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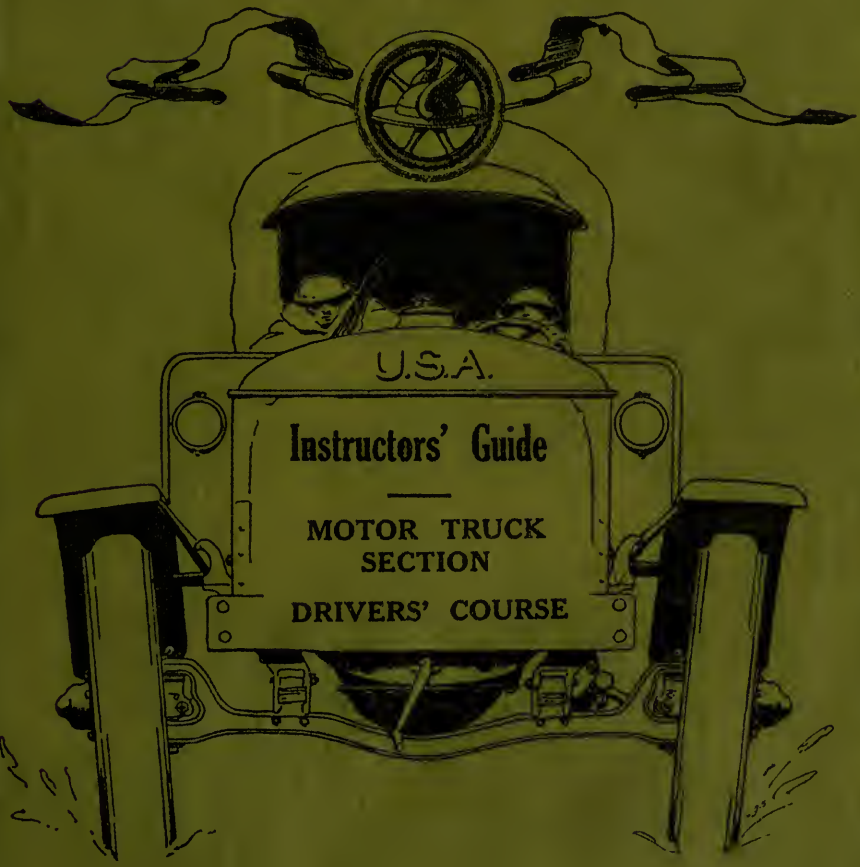
1919a

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION
TRAINING BRANCH



WASHINGTON, D. C.
November—1918

Class UC343
Book .A5
1919a

U.S. Motor transport corps.

MOTOR TRUCK SECTION DRIVERS' COURSE

OF THE

MOTOR TRANSPORT CORPS

M. T. C. Operation
M. T. C. Maintenance
M. T. C. Administration
Military Instruction
Laboratory

Shop Work
Lubrication
Cleaning, Oiling, Inspection
Knotting and Splicing

LENGTH OF COURSE, THREE WEEKS

Form MTC—429

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1917

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INDEX

M. T. C. Operation

LECTURE I. Motor Transport Company Organization.
LECTURE II. Road Rules.
LECTURE III. Road Rules.
LECTURE IV. Inspections.
LECTURE V. French Auto Terms.
Quiz Questions.
Written Examination.

M. T. C. Maintenance

LECTURE I. Type of Trucks.
LECTURE II. Repairs.
LECTURE III. Carburetors, Ignition, Transmission.
LECTURE IV. Clutches and Running Gear.
Quiz Questions.
Written Examination.

M. T. C. Administration

LECTURE I. The Soldier.
LECTURE II. Military Correspondence.
LECTURE III. Military Law.
LECTURE IV. Guard Duties.
Quiz Questions.
LECTURE V. Care of Arms and Equipment.
LECTURE VI. Care of Clothing and Equipment.
LECTURE VII. Company Organization.
LECTURE VIII. Stolen Property and Accident Reports.
LECTURE IX. M. T. C. Paper Work.
Quiz Questions.
Written Examination.

Military Instruction

References.

Laboratory

LECTURE I. Timing Gears and Valves.
LECTURE II. Carburetion and Ignition.
LECTURE III. Clutches and Gears.
LECTURE IV. Types of Power Plant.
LECTURE V. Tires and Accessories.

Shop Work

EXERCISE I. Ignition and Lighting.
EXERCISE II. Fuel System.
EXERCISE III. Steering Gear and Brakes.
EXERCISE IV. Trouble Shooting.

Lubrication

LECTURE I. Qualities of Oils and Methods of Application.
LECTURE II. Lubrication Troubles.
LECTURE III. Special Lubricants.
LECTURE IV. Gears and Wheel Hubs.

Cleaning, Oiling and Inspection

LECTURE I. General Discussion.
LECTURE II. General Discussion (Continued).

Knotting and Splicing

LECTURE I. Simple Knots and Splicings.

GENERAL STATEMENT

DIRECTIONS FOR INSTRUCTORS

Underlying all successful instruction must be the realization on the part of each man called upon to teach in any subject that all instruction is given for the student, not for the instructor. Obviously, then, the success of a teacher must be measured by the amount of his teaching which is converted into working knowledge by his students. The job, then, for every member of the instructing staff at every school is to put his information across so that the members of the class get it and are able to use it.

The results obtained in frequent quizzes, oral test questions, or the performance of duties by the student, which require the application of material taught, are the fundamental measures of the success of the instructor in his work. Too much emphasis should not be placed on set written examinations, for a great deal of information may be acquired and used in a poll parrot manner, allowing a man to get high rating on a written examination, but a very low rating on any examination in which the student must apply the knowledge obtained in class room to the performance of a definite task.

The instructor should also bear in mind that men learn most things through one, or more, of three senses: hearing, sight and touch, and that that instruction will be the most successful which permits the student to learn in the most ways. Furthermore, some men learn best by hearing, others, by touch, and still others by sight, so that no one method can be used with maximum success for all.

Having the foregoing facts in mind, every instructor, in preparing his work for class presentation, should plan to use, to the fullest possible extent, in the class, pieces of equipment, such as: rifles, pack equipment, parts of vehicle mechanism, such as axles, carburetors, spark plugs, or even whole chasses, if required, etc., etc. He should also use blackboards as much as possible for sketches, diagrams or definitions, etc., and should, so far as possible, insist that each student keep a note book in each subject, which must be neat in appearance and accurate in their statements. This will necessitate their inspection periodically, which should be done by the instructor or his assistants.

It will be seen that certain lectures are much shorter than would be required to fill the entire periods allotted to them. This is done purposely so that there will be an opportunity for the instructor to make up for lost time, occasioned by inspections, etc., etc.; or an opportunity for quizzes, special lectures, and such other work as the instructor may desire.

It will also be seen in the course for Motor Transport Company Mechanics that in places a four-hour period is devoted to certain lectures. This is done because the company mechanic must be a skilled workman and it is not enough for him to be informed on a subject; he must also be able to perform certain duties. The long lecture period permits reiteration, discussion and repeated demonstration on the part of the instructor, so that the student will get all details and be able to use his information. The instructor should use all his ability to put his ideas across in as many ways as possible to be sure that his class gets them thoroughly.

Instructors must look well to the discipline of their classes. Insistence should be placed on all students sitting in proper attitudes during class, and no lounging or otherwise careless appearance permitted. When the instructor enters the room, all students should rise and remain standing until ordered to

be seated. They should also rise when an officer enters the room and remain standing until otherwise directed. In short, strict military discipline should be insisted upon at all times by the instructor, and he should be especially careful that all his acts are also guided by the same precepts.

General Statement

The lectures in this book are designed for the use of the instructors in the various subjects, and are written from that standpoint, following the curriculum outline in detail.

The material is put in this form for the use of instructors so that training at all schools may be uniform. Copies of this book are not to be used for student's text books, and where any of the material contained in this book is desired for students' use it is expected that it will be reproduced by mimeograph or otherwise.

The lectures are not to be read to the students, but are to give the instructors the subject matter to be covered, as well as the method of presentation.

The material given under Exercises is written in lecture form but is to be covered by informal discussion, or otherwise, as the instructor may feel to be desirable.

Under quizzes and written examinations are given typical questions, not formal examinations as such. It is expected that the instructor will use such of the questions as he may wish for his work, but the main intent in setting down the questions is to give the instructor a standard of values by the aid of which he should be able to make up his own questions as need arises.

It is planned to issue bulletins on training activities once a month, for the use of instructors at all M. T. C. training camps. These bulletins will be sent in quantities to the Commanding Officers of all M. T. C. Training camps, for distribution, to the instructing personnel.

It will be well for instructors who are teaching mechanical subjects to secure the Instructor's Guide for Company Mechanics' Course as there are many details of the vehicle mechanism and diagrams that will be helpful in any work of that character.

No lectures are written on Military Instruction as the plan is to follow the reference books closely and have only informal lectures, recitations and quizzes.

Where lectures are prepared for periods not stated as lecture periods in the curriculum, it is designed that the material covered by the lecture will be given in an informal way during the period assigned for the work.

Some lectures will be found to be longer than others, and some will be found too short to cover the entire period assigned. This arrangement is made purposely to permit leeway to compensate for the personal equations of the various instructors, as well as to allow for hours lost or shortened by various unforeseen circumstances. Where spare time is provided by this means it is to be used in bringing up the work, if behind schedule, or for review or quiz, if the work is on schedule.

Motor Truck Drivers

Instructors will become familiar with the duties of the truck driver and use every effort to impress upon such students just what their duties are and especially what they are not to do. It must be borne in mind that the driver

does only the most elementary work on the truck, such as oiling and greasing, tightening loose bolts and nuts, changing spark plugs, filling the radiator, tightening loose wires, draining the carburetor, etc. He makes no actual repairs of any magnitude on the motor, or vehicle, except under the direction of the company mechanic. In view of the foregoing, the instruction should be confined to making the driver familiar with the construction of his vehicle and the relation of its parts, but not technically proficient in anything but the most minor repairs. Time may well be spent in training him to diagnose motor troubles by their symptoms, together with an understanding of their causes, so that he may know just what the trouble is, the seriousness of letting it go unattended, and the probable time required to make the repairs. Training of *truck drivers must* be restricted by the foregoing considerations.

Motor Car and Cycle Drivers

Motor Cars and Cycles operate as independent units, therefore the drivers must be taught not only the general mechanism, etc., of the vehicles, but also the road repairs and adjustments which are commonly made on vehicles by skilled operators. It is often impossible to get a mechanic for this work and the driver must be able to make repairs of such character as will be permanent, so the training of such men in maintenance, as well as driving, must be of a thorough nature.

Military Courtesies

It is designed that all students should be instructed in military courtesy and all commanding officers and senior instructors should have copies of the pamphlet on "Military Courtesies" published by the Training Branch, M. T. C. and see that all students are instructed in conformity with the directions therein contained.

The fact that an enlisted man completed a course in an M. T. C. School shall be recorded under "Remarks" on his Service Record, stating the course completed, the date and the general average of his work.

M. T. C. Training Publications

The following material may be obtained in quantities as desired by application to the Chief, Training Branch, Motor Transport Corps, Washington, D. C.

A. Report Forms for Use in M. T. C. Courses.

1. Motor Transport Company Officers' Course, Forms M. T. C.-289 and M. T. C.-290.
2. Motor Transport Company Truckmasters' Course, Forms M. T. C.-291 and M. T. C.-292.
3. Motor Truck Drivers' Course, Forms M. T. C.-293 and M. T. C.-294.
4. Motor Car Drivers' Course, Forms M. T. C.-295 and M. T. C.-296.
5. Motor Cycle Company Officers' Course, Forms M. T. C.-297 and M. T. C.-298.
6. Motorcycle Drivers' Course, Forms M. T. C.-299 and M. T. C.-300.
7. Motor Transport Company Mechanics' Course, Forms M. T. C.-301 and M. T. C.-302.

B. Tables of instructional personnel for schools of different sizes.
C. Tables of equipment for schools of different sizes.
D. Blank diplomas for awarding to students in officers' courses at the completion of their courses.
E. M. T. C. Curriculum of Field Service Training.
F. Tentative Manual of Training of the Motor Transport Corps.
G. Instructors' Guide for Motor Transport Company Officers' Course.
H. Instructors' Guide for Motor Transport Company Non-Commissioned Officers' Course.
I. Instructors' Guide for Motor Transport Company Drivers' Course.
J. Instructors' Guide for Motor Car Compnay Drivers' Course.
K. Instructors' Guide for Motor Cycle Company Officers' Course.
L. Instructors' Guide for Motor Cycle Company Drivers' Course.
M. Instructors' Guide for Motor Transport Company Mechanic's Course.
N. Curriculum and Lectures for the M. T. C. Administrative Officers' Course.
O. Course in Military Courtesies.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

SCHEDULE OF CLASSES

On the following pages is shown the arrangement of classes necessary for four sections of students in training at the same time.

The schedule is planned to secure the maximum use of housing, equipment and instructing staff, and the requirements for housing, equipment and instructors are based upon the assumption that such a schedule will be followed in the school.

It will be noted that the students are divided into two groups, one of which has class room work in the morning, while the other group is receiving road instruction, and in the afternoon the groups exchange places. In order to make the fullest use of laboratory equipment, each of the large groups is divided into two smaller groups, or sections. While one section of one group is receiving lecture instruction for two hours, the other section is in the laboratory, and at the end of the two-hour period, the sections exchange, so that those that have had laboratory work go to lectures for the next two hours, and the other section goes into the laboratory. Both sections of the other group are on the road at the same time receiving the same instruction.

Under special conditions it may be necessary to modify these schedules, and it is expected that the officials at any school will use their judgment in the matter.

The days assigned to full day convoys are planned for the two groups so that all trucks may be used by that group which is to go on the convoy, the work of the other group being confined to class room work, or Ford, or motorcycle driving.* On the day after an all day convoy the vehicles should be cleaned, oiled and inspected by that group which used them on the convoy, and the schedule is planned with that end in view.

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*NOTE.—In cases where a driver is skillful on both trucks and cars, it is well to instruct him in the operation of motorcycles as well.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

FIELD SERVICE TRAINING

Motor Truck Company Drivers' Course

Length: Three Weeks

FIRST SECTION

First Week

Day	6.30-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00	1.00-2.00	2.00-3.00	3.00-4.00	4.00-5.00	6.30-10.00
1	Infantry Drill Exercise I	M. T. C. Operation Lecture I	M. T. C. Administration Lecture I	Laboratory Exercise I		Convoy Trade Test				
2	Infantry Drill Exercise II	M. T. C. Operation Lecture II	M. T. C. Administration Lecture II	Lubrication Exercise I		Convoy Preliminary Driving Exercise I				
3	Infantry Drill Exercise III	M. T. C. Maintenance Lecture I	M. T. C. Administration Lecture III	Shop Practice Exercise I		Convoy Exercise I				
4	Infantry Drill Exercise IV	M. T. C. Operation Lecture III	M. T. C. Administration Lecture IV	Laboratory Exercise II						Convoy Exercise II
5	Infantry Drill Exercise V	M. T. C. Maintenance Lecture II	M. T. C. Administration Lecture V	Lubrication Exercise II		Convoy Exercise III				
6	Infantry Drill Exercise VI	M. T. C. Operation Lecture IV	M. T. C. Administration Quiz	Shop Practice Exercise II		Cleaning, Oiling and Inspection Exercise I				

Second Week

7	Infantry Drill Exercise VII	Convoy Exercise IV								
8	Infantry Drill Exercise VIII	Cleaning, Oiling and Inspection Exercise II				Convoy Ford Driving Exercise V				
9	Infantry Drill Exercise IX	M. T. C. Maintenance Quiz	M. T. C. Operation Quiz	Laboratory Exercise III						Convoy Exercise VI
10	Infantry Drill Exercise X	M. T. C. Operation Lecture V	M. T. C. Administration Lecture VI	Lubrication Exercise I.I		Knotting and Splicing Exercise I				
11	Infantry Drill Exercise XI	M. T. C. Maintenance Lecture III	M. T. C. Administration Lecture VII	Shop Practice Exercise III		Convoy Exercise VII				
12	Infantry Drill Exercise XII	M. T. C. Operation Quiz	M. T. C. Administration Quiz	Laboratory Exercise IV		Cleaning, Oiling and Inspection Exercise III				

Third Week

13	Infantry Drill Exercise XIII	Convoy Exercise VIII								
14	Infantry Drill Exercise XIV	Cleaning, Oiling and Inspection Exercise IV				Convoy Exercise IX				
15	Infantry Drill Exercise XV	M. T. C. Maintenance Quiz	M. T. C. Operation Quiz	Lubrication Exercise IV		Convoy Ford Driving Exercise X				
16	Infantry Drill Exercise XVI	M. T. C. Operation Quiz	M. T. C. Administration Lecture VIII	Shop Practice Exercise IV						Convoy Exercise XI
17	Infantry Drill Exercise XVII	M. T. C. Maintenance Lecture IV	M. T. C. Administration Lecture IX	Laboratory Exercise V		Convoy Exercise XII				
18	Infantry Drill Exercise XVIII	M. T. C. Operation Quiz	M. T. C. Maintenance Quiz	M. T. C. Administration Quiz		Cleaning, Oiling and Inspection Exercise V				

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

FIELD SERVICE TRAINING

Motor Truck Company Drivers' Course

Length: Three Weeks

SECOND SECTION

First Week

Day	6.30-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00	1.00-2.00	2.00-3.00	3.00-4.00	4.00-5.00	6.30-10.00
1	Infantry Drill Exercise I	Convoy Trade Test				M. T. C. Operation Lecture I	M. T. C. Administration Lecture I	Laboratory Exercise I		
2	Infantry Drill Exercise II	Convoy Preliminary Driving Exercise I				M. T. C. Operation Lecture II	M. T. C. Administration Lecture II	Lubrication Exercise I		
3	Infantry Drill Exercise III	Convoy Exercise I				M. T. C. Maintenance Lecture I	M. T. C. Administration Lecture III	Shop Practice Exercise I		Convoy Exercise II
4	Infantry Drill Exercise IV					M. T. C. Operation Lecture III	M. T. C. Administration Lecture IV	Laboratory Exercise II		
5	Infantry Drill Exercise V	Convoy Exercise III				M. T. C. Maintenance Lecture II	M. T. C. Administration Lecture V	Lubrication Exercise II		
6	Infantry Drill Exercise VI	Cleaning, Oiling and Inspection Exercise I				M. T. C. Operation Lecture IV	M. T. C. Administration Quiz	Shop Practice Exercise II		

Second Week

Day	6.30-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00	1.00-2.00	2.00-3.00	3.00-4.00	4.00-5.00	6.30-10.00
7	Infantry Drill Exercise VII	Knotting and Splicing Exercise I				M. T. C. Operation Lecture V	M. T. C. Administration Lecture VI	Lubrication Exercise III		
8	Infantry Drill Exercise VIII	Convoy Ford Driving Exercise V				M. T. C. Maintenance Lecture III	M. T. C. Administration Lecture VII	Shop Practice Exercise III		
9	Infantry Drill Exercise IX	Cleaning, Oiling and Inspection Exercise II				M. T. C. Operation Quiz	M. T. C. Administration Quiz	Laboratory Exercise III		
10	Infantry Drill Exercise X	Convoy Exercise IV								
11	Infantry Drill Exercise XI					Cleaning, Oiling and Inspection Exercise III				Convoy Exercise VI
12	Infantry Drill Exercise XII	Convoy Exercise VII				M. T. C. Maintenance Quiz	M. T. C. Operation Quiz	Laboratory Exercise IV		

Third Week

Day	6.30-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00	1.00-2.00	2.00-3.00	3.00-4.00	4.00-5.00	6.30-10.00
13	Infantry Drill Exercise XIII	Convoy Ford Driving Exercise X				M. T. C. Operation Quiz	M. T. C. Administration Lecture VIII	Shop Practice Exercise IV		
14	Infantry Drill Exercise XIV					M. T. C. Maintenance Lecture IV	M. T. C. Administration Lecture IX	Laboratory Exercise V		
15	Infantry Drill Exercise XV	Convoy Exercise VIII								
16	Infantry Drill Exercise XVI	Cleaning, Oiling and Inspection Exercise IV				M. T. C. Operation Quiz	M. T. C. Maintenance Quiz	M. T. C. Administration Quiz		
17	Infantry Drill Exercise XVII	Convoy Exercise IX				Cleaning, Oiling and Inspection Exercise V				Convoy Exercise XI
18	Infantry Drill Exercise XVIII	Convoy Exercise XII				M. T. C. Maintenance Quiz	M. T. C. Operation Quiz	Lubrication Exercise IV		

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

FIELD SERVICE TRAINING

Motor Truck Company Drivers' Course

Length: Three Weeks

THIRD SECTION

First Week

Day	6.30-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00	1.00-2.00	2.00-3.00	3.00-4.00	4.00-5.00	6.30-10.00
1	Infantry Drill Exercise I	Laboratory Exercise I		M. T. C. Operation Lecture I	M. T. C. Administration Lecture I	Convoy Trade Test				
2	Infantry Drill Exercise II	Lubrication Exercise I		M. T. C. Operation Lecture II	M. T. C. Administration Lecture II	Convoy Preliminary Driving Lesson I				
3	Infantry Drill Exercise III	Shop Practice Exercise I		M. T. C. Maintenance Lecture I	M. T. C. Administration Lecture III	Convoy Exercise I				
4	Infantry Drill Exercise IV	Laboratory Exercise II		M. T. C. Operation Lecture III	M. T. C. Administration Lecture IV					Convoy Exercise II
5	Infantry Drill Exercise V	Lubrication Exercise II		M. T. C. Maintenance Lecture II	M. T. C. Administration Lecture V	Convoy Exercise III				
6	Infantry Drill Exercise VI	Shop Practice Exercise II		M. T. C. Operation Lecture IV	M. T. C. Administration Quiz	Cleaning, Oiling and Inspection Exercise I				

Second Week

7	Infantry Drill Exercise VII	Convoy Exercise IV								
8	Infantry Drill Exercise VIII	Cleaning, Oiling and Inspection Exercise II				Convoy Ford Driving Exercise V				
9	Infantry Drill Exercise IX	Laboratory Exercise III		M. T. C. Maintenance Quiz	M. T. C. Operation Quiz					Convoy Exercise VI
10	Infantry Drill Exercise X	Lubrication Exercise III		M. T. C. Operation Lecture V	M. T. C. Administration Lecture VI	Knotting and Splicing Exercise I				
11	Infantry Drill Exercise XI	Shop Practice Exercise III		M. T. C. Maintenance Lecture III	M. T. C. Administration Lecture VII	Convoy Exercise VII				
12	Infantry Drill Exercise XII	Laboratory Exercise IV		M. T. C. Operation Quiz	M. T. C. Administration Quiz	Cleaning, Oiling and Inspection Exercise III				

Third Week

13	Infantry Drill Exercise XIII	Convoy Exercise VIII								
14	Infantry Drill Exercise XIV	Cleaning, Oiling and Inspection Exercise IV				Convoy Exercise IX				
15	Infantry Drill Exercise XV	Lubrication Exercise IV		M. T. C. Maintenance Quiz	M. T. C. Operation Quiz	Convoy Ford Driving Exercise X				
16	Infantry Drill Exercise XVI	Shop Practice Exercise IV		M. T. C. Operation Quiz	M. T. C. Administration Lecture VIII					Convoy Exercise XI
17	Infantry Drill Exercise XVII	Laboratory Exercise V		M. T. C. Maintenance Lecture IV	M. T. C. Administration Lecture IX	Convoy Exercise XII				
18	Infantry Drill Exercise XVIII	M. T. C. Administration Quiz		M. T. C. Operation Quiz	M. T. C. Maintenance Quiz	Cleaning, Oiling and Inspection Exercise V				

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

FIELD SERVICE TRAINING

Motor Truck Company Drivers' Course

Length: Three Weeks

FOURTH SECTION

First Week

Day	6.30-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00	1.00-2.00	2.00-3.00	3.00-4.00	4.00-5.00	6.30-10.00
1	Infantry Drill Exercise I	Convoy Trade Test				Laboratory Exercise I		M. T. C. Operation Lecture I	M. T. C. Administration Lecture I	
2	Infantry Drill Exercise II	Convoy Preliminary Driving Lesson I				Lubrication Exercise I		M. T. C. Operation Lecture II	M. T. C. Administration Lecture II	
3	Infantry Drill Exercise III	Convoy Exercise I				Shop Practice Exercise I		M. T. C. Maintenance Lecture I	M. T. C. Administration Lecture III	Convoy Exercise II
4	Infantry Drill Exercise IV					Laboratory Exercise II		M. T. C. Operation Lecture III	M. T. C. Administration Lecture IV	
5	Infantry Drill Exercise V	Convoy Exercise III				Lubrication Exercise II		M. T. C. Maintenance Lecture II	M. T. C. Administration Lecture V	
6	Infantry Drill Exercise VI	Cleaning, Oiling and Inspection Exercise I				Shop Practice Exercise II		M. T. C. Operation Lecture IV	M. T. C. Administration Quiz	

Second Week

Day	6.30-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00	1.00-2.00	2.00-3.00	3.00-4.00	4.00-5.00	6.30-10.00
7	Infantry Drill Exercise VII	Knotting and Splicing Exercise I				Lubrication Exercise III		M. T. C. Operation Lecture V	M. T. C. Administration Lecture VI	
8	Infantry Drill Exercise VIII	Convoy Ford Driving Exercise V				Shop Practice Exercise III		M. T. C. Maintenance Lecture III	M. T. C. Administration Lecture VII	
9	Infantry Drill Exercise IX	Cleaning, Oiling and Inspection Exercise II				Laboratory Exercise III		M. T. C. Operation Quiz	M. T. C. Administration Quiz	
10	Infantry Drill Exercise X	Convoy Exercise IV								
11	Infantry Drill Exercise XI					Cleaning, Oiling and Inspection Exercise III				Convoy Exercise VI
12	Infantry Drill Exercise XII	Convoy Exercise VII				Laboratory Exercise IV		M. T. C. Mainteoxnce Quiz	M. T. C. Operation Quiz	

Third Week

Day	6.30-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00	1.00-2.00	2.00-3.00	3.00-4.00	4.00-5.00	6.30-10.00
13	Infantry Drill Exercise XIII	Convoy Ford Driving Exercise X				Shop Practice Exercise IV		M. T. C. Operation Quiz	M. T. C. Administration Lecture VIII	
14	Infantry Drill Exercise XIV					Laboratory Exercise V		M. T. C. Maintenance Lecture IV	M. T. C. Administration Lecture IX	
15	Infantry Drill Exercise XV	Convoy Exercise VIII								
16	Infantry Drill Exercise XVI	Cleaning, Oiling and Inspection Exercise IV				M. T. C. Administration Quiz		M. T. C. Operation Quiz	M. T. C. Maintenance Quiz	
17	Infantry Drill Exercise XVII	Convoy Exercise IX				Cleaning, Oiling and Inspection Exercise V				Convoy Exercise XI
18	Infantry Drill Exercise XVIII	Convoy Exercise XII				Lubrication Exercise IV		M. T. C. Maintenance Quiz	M. T. C. Operation Quiz	

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

M. T. C. OPERATION

LECTURE I

It is difficult to state definitely just what services the men of the Motor Transport Corps will perform. Some companies will be used in the transporting of troops, some in hauling engineers' material, some quartermasters' supplies, etc. Some companies will be attached to depots, while others will be with different organizations. In fact the Motor Transport Corps will be subject to many kinds of work; therefore we will give a general outline of all that may be expected. A great deal of the work will have to be learned by experience.

One of the most important factors in the Motor Transport Corps is military discipline. It is necessary that every driver should understand why it is important that we have rigid road discipline. Without it the entire organization would be a failure.

The Government uses several makes of vehicles: The Liberty, White, Packard, Kelly, Pierce-Arrow and several others. Each has its own type of gear shift, etc., but as a whole they are all much the same; in fact, all have the internal combustion engine known as the 4-stroke type, with a three-or four-speed transmission. The rear construction in all is practically the same except on the four-wheel drive and the Nash Quad. These details are covered in the technical lectures, so it will not be necessary to go into them here.

Without doubt a large part of your work will be transporting infantry, taking them up to the front and bringing them back. It must be remembered that these men are working hard day and night, at times days without sleep, therefore it is your duty as a driver and a brother soldier to make it as comfortable as possible for them. The driver is in charge of his truck and the assistant driver is under him. It is the duty of the driver to see that his assistant handles the men courteously and treats them kindly. Of course discipline here, as in all other cases, must be maintained, but at the same time show the men every consideration that your rules and equipment permit. For example, putting the cover up when the sun is very hot, taking the bumps easily and using your best judgment at all times to insure the comfort of the men.

Transportation of supplies is of vital importance and the driver plays an important part in moving cargoes. While he does not do the loading and unloading (a detail is always furnished for that work), it is his duty to see that the load is placed on his machine properly and that it is lashed correctly before starting. He should be careful that goods, boxes, etc., are not broken while being loaded or unloaded, as material overseas is worth many times more than it costs in this country. It is up to every driver, assistant driver, and man in the M. T. C. to help in the conservation of everything shipped overseas.

Too much cannot be said in regard to the loading of a vehicle. Inefficient loading not only reduces the carrying capacity but it also endangers the safety of the cargo. A poorly loaded truck with the cargo swaying from side to side is in constant danger of turning over. This not only makes the driving much

harder, but causes undue wear on the vehicle. Overloading has the same effect and should be guarded against.

In loading heavy goods the load should be equally distributed with the heavy goods placed over the rear axle so as to increase traction.

Hooks should never be used in handling sacks. Sacks must be firmly placed. It is the duty of a driver to watch his cargo in the loading, as the men who are doing the loading usually know nothing about proper distribution and they are thoughtless in handling cargoes.

Some of the difficulties on the other side are narrow roads, corduroy roads, roads torn by shell fire, etc., and at times the driver will think it almost impossible to deliver his cargo, but by living up to the rules of the M. T. C. and at all times loading his truck properly he will have little trouble.

Transportation of ordnance is of equal importance. Care should be taken in the handling of all ordnance. Caution should be exercised to insure protection of the load from the rain and sun. Loading should be done with great care so as to insure safe delivery.

The driver should know something about the personnel of a Motor Transport Company. A company consists of one first lieutenant who is the commanding officer, one second lieutenant who acts as assistant to the commanding officer, one truckmaster who is the first sergeant, three assistant truckmasters, one mess sergeant, one supply sergeant, one chief mechanic and two assistant mechanics, one company clerk, 32 corporal drivers, 9 privates, (first class (assistant drivers), one private, first class (messenger) and 24 privates who are assistant drivers.

In a company we have one light open 5-passenger motor car, 27 cargo trucks (class B), one kitchen trailer, one or two tank trucks, and 2 cargo trucks (class AA), one being a light repair truck and the other for company supplies. The 27 cargo trucks are used for hauling purposes only; such as hauling troops, etc. These are known as Class B trucks and are three-ton or over.

The light repair truck carries a supply of small parts and tools such as could not be carried in the tool boxes of the cargo truck. The tank truck carries a supply of gasoline and oil for the company. This is not needed in the train in short runs. The commander also has a motorcycle with a side car which is used by the truckmaster or the chief mechanic.

At times the entire company may be attached to a train, when it operates under the direction of a train commander. A motor truck company may also be assigned to duty with an infantry organization. In that case, the infantry commander designates its duties, but the company is under the command of the M. T. C. officer.

The motor supply train usually consists of six motor truck companies, though two or more are called a train. As stated before the train is operated by a train commander who is a captain. All reports, etc., of each company go through his office. This is known as a headquarters command, having one captain, one first lieutenant as assistant to the commander and adjutant, and one first lieutenant as mechanical inspector, one second lieutenant who is the train supply officer, one sergeant, first class (mechanical inspector), one sergeant, first class (sergeant major), and one sergeant, first class (supply sergeant), two sergeant clerks, four corporals who are drivers, and two privates, first class (motorcycle drivers), making a total enlisted personnel of eleven, and four officers, an aggregate of fifteen men.

The motor equipment of a headquarters motor command consists of one light closed car and one light open car for the officers' use, one cargo (class AA) truck for supplies, and two motorcycles with side cars for general service.

It is of the utmost importance that every man know all of the road rules and understand them thoroughly. They are as follows:

1. The driver will keep his truck on the right of the road at all times whether standing or moving.

2. In passing vehicles traveling *in the same direction* the driver will pass *on the left* and sound his horn.

3. A driver *when meeting a vehicle* will always pass it *on the right* and give it half of the road.

4. Never block the road.

5. In passing a standing or moving convoy the driver will slow down and sound his horn.

6. When a convoy is halted all men must keep off the road.

7. The convoy must be kept together.

8. The assistant driver must at all times keep driver in touch with truck immediately behind in order that the speed may be uniform.

9. A driver will never abandon his vehicle except on order of his commanding officer.

10. Drivers will not permit unauthorized persons to ride on vehicle.

11. If any repairs are needed the driver will report same immediately.

12. The military police on duty will be strictly obeyed.

13. The use of muffler cut-out is absolutely forbidden at all times.

14. When vehicles are standing motors will not be left running to exceed one minute.

15. Appropriate signals will be given when changing direction or stopping.

16. Examine amount of oil, gasoline and water after each stop.

17. Investigate and find the cause of all unusual noises.

18. Do not smoke while driving.

19. Engine is to be used as a brake when descending hill by shifting to a lower gear.

20. When a vehicle is stopped on a hill put a block or stone under one rear wheel.

21. A motor vehicle will not be driven by anyone except the regular driver or assistant driver assigned to same, unless in case of emergency.

22. Never use a naked flame or oil lantern when filling gasoline tank or working on the carburetor; use electric torch.

23. When driving in cities, towns or villages, never double a vehicle moving in the same direction.

24. A slower moving convoy must never be doubled unless the commander of overtaking convoy makes certain that doubling can be completed without confusion.

25. Never double a halted convoy, a halted body of troops or a body of troops moving in the same direction without first gaining consent of the officer in charge.

These are the general rules and must be obeyed at all times except when in the advanced zone, where they may be superseded by orders from the military police or by posted signs.

Driver's accident report is known as M. T. C. Form 124. Each motor vehicle is supplied at all times with this form. In case of accident, however trivial, which results in injury to person or property, the driver of any government vehicle will fill in the information called for on the form and will then deliver it to his commanding officer, who will certify in writing on the form, the day and hour of delivery of the report. Court martial proceedings will immediately be started against any driver who fails to make this report.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

M. T. C. OPERATION

LECTURE II

Today we will take up the speed limits of different vehicles in open and closed formation. In cities, towns and villages no type of cargo trucks may exceed a speed of 8 miles an hour. The maximum speed limit for passenger cars, ambulances and motorcycles in towns, villages and cities is 10 miles an hour.

Trucks in open formation, in open country, in or out of convoy must not exceed 12 miles per hour.

Ambulances must not exceed 14 miles an hour, and the maximum speed for passenger cars and motorcycles is 35 miles an hour in open country.

All vehicles in the Motor Transport Corps must slow down to 6 miles an hour crossing bridges.

While 27 cargo trucks constitute a convoy company, two or more trucks are called a convoy, and observe all convoy rules, regulations, etc.

A company has three sections of nine vehicles each, the sections being designated by yellow discs; the end of a section is indicated by one disc and the end of a company by two.

The truckmaster is the first sergeant of a motor truck company. He oversees all dispatches, administration, etc., attends to all fatigue details and roll calls, and transmits all requirements of the company to the commanding officer. The truckmaster is directly responsible to the company commander for the condition of the company. He helps the commander in all inspections, acts as first sergeant in all formations, etc.

The assistant truckmaster is the chief of his section and is responsible for the discipline and instruction of the drivers and assistant drivers assigned to his section. He is responsible for the operation and repair of the vehicles in his section. It is his duty to enforce sanitary and military regulations in the field and quarters and to keep in close touch with his men (he is the intermediary between his men and the truckmaster), seeing at all times that the men have the proper equipment and clothing. All orders for his section or for any member of his section must go through the assistant truckmaster; therefore it is of vital importance that the assistant truckmaster be ever on the watch. Should he fail to pass any signal on, it might split not only the company but the entire train. He must co-operate and work closely with the truckmaster. It is his duty to inspect the equipment at intervals and to have his section always ready for inspection. He should also examine the vehicles after a long run or on return from work. In his absence he will appoint or recommend that the commanding officer name one of his best drivers to act as assistant truckmaster.

Each driver is assigned to a vehicle; he must sign for this truck and its equipment and must keep the vehicle and tools clean at all times. It is his duty to see that it is always ready for inspection by the train or company commander or by the truckmaster, assistant truckmaster, company mechanic or his assistants.

The assistant driver must work with the driver at all times. He must receive and pass all signals on and notify the driver of same. The assistant driver should take great care in passing on the starting and stopping signals. He should not raise his hand or pass the starting signal until he is sure that the driver is ready to move; that is, he must wait until the driver has the clutch disengaged and the vehicle in first gear. In stopping he should notify the assistant driver behind by holding his arm stiff and at an angle of 45 degrees above the horizontal.

The efficiency of the company, the way it keeps its distance, etc., depends upon the rapid transmission of signals by the assistant drivers.

The repair trucks carry all the necessary equipment to make small repairs, such as soldering radiators, putting in new gaskets, and other work that can be finished within a short time. The chief mechanic is in charge of the repair truck. It is the duty of the truckmaster to assign the assistant mechanic to sections and see to it that they perform their work properly. One of the assistant mechanics acts as chief in the absence of the chief mechanic.

The chief mechanic signs for the mechanical equipment. He also keeps the spare parts equipment up to standard. The assistant mechanic makes all reports to the chief mechanic.

The repair truck or service truck usually is the last truck in the company.

One of the most important things for the driver to remember is the control of speed. *The speed of a convoy is controlled by the last truck;* therefore, it is the duty of the driver to see that the assistant driver is at all times watching the vehicle in the rear.

The distance is taken from the vehicle in front. The driver should never look back; the assistant driver does this. There is no reason for the convoy to become separated. If by any chance the convoy should be split, the assistant driver should pass forward the *slow down signal.* This does not mean that the company should be stopped. In case a truck breaks down it should be driven to the side of the road, the other trucks passing around it. The space left by the disabled truck should be closed in by the following trucks. When the broken truck is repaired by the mechanic it falls in at the rear. In case the last truck of a section breaks down the disc would have to be changed.

The driver should never leave the truck or permit the assistant driver or any of the troops he may be hauling to leave the truck without proper authority.

All drivers should know the convoy distances in close, open and halted formations. They are as follows:

Between *trucks* in towns, cities and villages, 7 yards or one truck-length. Between *sections* in towns, cities and villages, 20 yards or 3 truck-lengths. Between *companies* in towns, cities and villages, 40 yards or 6 truck-lengths. Between *trains* in towns, cities and villages, 100 yards or 14 truck-lengths.

Between *trucks* in open formation, 20 yards or 3 truck-lengths. Between *sections* in open formation, 40 yards or 6 truck-lengths. Between *companies* in open formation, 80 yards or 12 truck-lengths. Between *trains*, 100 yards or 15 truck-lengths.

Halted formation is the same as close formation.

The distance between motor cars is 40 yards in open formation. Between sections, 60 yards.

In close formation, 7 yards between cars and 20 yards between sections.

Going over bridges convoy should spread out so that not more than one truck is on one span of the bridge at one time.

Backing a truck the assistant driver should jump out in front of the truck, forearms raised vertically, hands in front of and opposite shoulders and move arms forward and back, horizontally, palms held toward the truck. Back of hands toward the truck signals forward movement.

If man signaling backing directions desires that the vehicle be moved to the left he holds the right hand on the chest and moves the left arm sharply to the left; if he desires that the vehicle be backed to the right he holds his left hand on his chest and moves his right arm sharply to the right. The assistant driver should use great care with these signals, as the driver must not look back but must depend on the assistant to guide him properly. If the assistant wants the driver to move faster he indicates so by moving has arms more rapidly in the direction the truck is to go. To stop the vehicle the arms are moved sharply to the side from the backing position and then dropped sharply to natural position.

Convoy signals are given verbally, visually and with a whistle. As a usual thing in convoy the truckmaster gives both visual and whistle signals.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

M. T. C. OPERATION

LECTURE III

It is the purpose of this lecture to take up the rules of the road. We shall go into this very carefully as every one must realize the necessity of a complete understanding of road directions. Some of the routes over which the convoy or trucks will pass are called *routes gardees.* These roads are policed by French soldiers who will be unable to explain or discuss details with you. If you master the regulations and study the road signs so that when you see them you instinctively and instantaneously know and understand their exact meaning, you will never cause any trouble.

Routes gardees are important communicating roads between points along the French front. In the *Zone d'Armee* or Zone of the Advance the *routes gardees* are always policed by guards who wear an arm band of green and white.

The following rules of the *routes gardees* will be strictly complied with:

(a) All signs and notices must be strictly obeyed.
(b) All instructions given by route police must be complied with even if they are contrary to your original instructions.
(c) Never pass (or double) any motor vehicle that is proceeding in the same direction you are going while on a route gardee. Passenger cars are not included in this ruling.
(d) Never stop your truck on a route gardee. If you break down and must stop for repairs, before stopping get your truck over to the right as far as possible by towing or by any other means, so that you will not interfere with the traffic. If there is not sufficient space when you are over as far to the right as you can move, you will then have to be pulled or towed completely off the road.
(e) A distance of 50 yards between sections should be observed.
(f) Never turn your vehicle around on a route gardee.

The following much used French road signs, here translated, should be memorized:

FRENCH.	ENGLISH.
Ralentir	Slow up.
Passage a Niveau	Railroad grade crossing.
Tenez Votre Droit	Keep to the right.
Virage	Sharp turn ahead.
Cassis	Bad bump ahead.
Sens Unique	One way only.
Defense de Doubler	Do not pass any vehicle going in same direction.
Vitesse Maxima	Full speed.
Sens Obligatoire	Must follow direction indicated.
Convois Double Circulation	Convoys may run in either direction.
Croisement	Cross roads.
Cette route est observer par l'ennemi	This road is observed by the enemy.
Extendre les lumiere	Turn out lights.

There are several other simple French words that would be helpful to remember. It is suggested that they be memorized, as there will be many times when you will find use for them in France. For example, driving along a road at night you will be challenged by a sentinel. If it is one of our boys you are all right, but if it is a French sentry you must be able to satisfy him who you are. He will challenge you always with "*Halt-o-la!*" which means halt. Then he will say "*Qui vive!*" which means "Who goes there?" You must answer "American," when he will return "*Avancez au ralliement,*" which means, "Advance and give the countersign." You will be supplied with the countersign each day by your commanding officer.

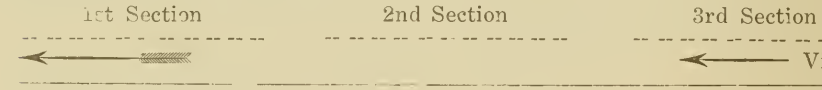
When you are working down some lonely road taking ammunition to a field battery you are very likely to be challenged at any moment.

Other signs and words one will see are:

FRENCH.	ENGLISH.
Defendu	Not permitted.
Allez	Go or go on.
Chemin de fer	Railroad.
Voiture	Auto or truck.
Doucement	Slowly.
Tournez a droit	Turn to the right.
Tournez a gauche	Turn to left.
En evant	Straight ahead.
A l'arriere	To the rear.

Two or more vehicles operating together on the same road constitute a convoy. The last vehicle in each section shall carry on the rear left-hand side a yellow disc about 12 inches in diameter. On the last vehicle in line there shall be two yellow discs. Whenever possible there shall be on each truck a driver and assistant driver. It is the driver's duty to drive the truck and the assistant driver's duty to watch all signals and to communicate them to the driver. He will observe whether the truck behind is following, and pass the necessary signals to vehicles in convoy. He relieves the driver when necessary on long convoys.

You will find when you come to the problem of transporting troops that it is about the hardest job you will handle in the transport work. Supplies don't move around, but men do; therefore you will be required to be right on the job and get your men loaded without confusion and in regular military manner. In preparation for this form of transportation, the section or sections, as the case may be, proceed to the town where the troops are to be loaded, and pass through empty, stopping on the other side with the last truck of the last section at the edge of the village, for example:



The troops pass down the road from the village in column of twos. The assistant truckmaster of each section assembles the assistant drivers in the order that their trucks occupy in the section. The first section marches to the end of the company, followed in turn by the second and third, or as many sections as there are. All assistant drivers now occupy the same positions opposite the company as their trucks occupy in the section. The company commander counts off the first 20 men to be loaded and the assistant driver of the first truck marches them off; this takes place with the next 20 and so on until all men are assigned. In the meantime the driver of each truck lets down the tail-board and puts up the benches and the truck is ready to be loaded upon the arrival of the assistant driver and 20 men assigned. All rifles and equipment are placed under the seat and the tail-board secured in position.

Drivers will remember that as far as the trucks are concerned, they are in charge. No one can tell you how to run or what to do; your speed, etc., will be regulated according to the orders of your company commander.

When you are unloading troops, pass through a town and unload on the other side, especially after a long convoy. If you discharge your troops in town you have to proceed through them in the street, and some one is likely to be injured. Always make the men as comfortable as possible. Your company commander will stop the company every three hours or so on long convoys to allow the men to perform all necessary duties.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

M. T. C. OPERATION

LECTURE IV

Formal inspection at *company front* is usually held in the company park. The trucks are lined up in a straight line. This is called line formation, the first truck always being used as a right guide.

The distance between trucks is 2 yards and the distance between sections is 4 yards.

The commander takes position 1 yard to the right and 2½ yards in advance of the right front hub of the staff car. The second in command takes position 1 yard to the right and 2 yards in advance of the right front hub of the staff car. The truckmaster takes position 18 inches to the right and 2 yards in advance of the right front hub of the staff car, just behind the second in command. Each assistant truckmaster takes position 1 yard to the right and 1½ yards in advance of the right front hub of the first truck in his section. The chief mechanic takes position 1 yard to the left and 1½ yards in advance of the left front hub of the repair truck. The assistant mechanics take position 1 yard to the rear of the assistant drivers of the first and second sections. The driver of each vehicle takes position immediately behind the right front hub of his vehicle, his left sleeve touching the fender. The assistant driver takes position immediately behind the left front hub, his right sleeve touching the fender. The motorcycle driver takes position in line with the front hub of his vehicle and against the side car.

Inspection in *column of sections* and *column of trucks* is held in the same formation, the personnel taking relatively the same positions.

The vehicles at a formal inspection must be thoroughly clean, all the joints wiped, grease cups turned down and the fresh grease showing. While the vehicles must be in shape at all times, the commanding officer usually informs his truckmaster when, where, and at what time the inspection is to be held.

There are times on long convoys when the company will not return to the park for weeks. In this case the inspection is held in the same manner as at the regular barracks on Saturday morning. The men must have a neat appearance, hair cut, shaved, shoes shined, clothes clean, etc. The vehicles must be ready for inspection. As a usual thing the inspection is held on Saturday morning, but if the company is in convoy it may be held at any time the commanding officer may direct.

Informal inspection by the company commander, truckmaster, assistant truckmaster and mechanics should be held daily or at frequent intervals. At informal inspections, inspectors should be on the lookout for all leaks and unusual noises, and they should make sure that the grease has actually been forced into the bearings. They should examine nuts and bolts to make sure that they are tight. The driver should assist in these inspections. It is the duty of the driver to watch for loose bolts and nuts, and spend his spare time oiling and greasing. The driver who can show that he has no trouble with his vehicle and always passes inspection, when he and his truck always have a clean appearance, is certain to be in line for promotion.

A driver and assistant should know how to handle ammunition. They should know the standard truck equipment, and the number of different articles. They should have some knowledge of the standard articles of Quartermaster property and the capacity required for same in crates, barrels and boxes. They should know the amounts that can be loaded in a type AA cargo truck. We cannot go into detail on these things nor do we expect the driver will know all of them, but he should have a general idea.

Full descriptions of inspection formations with diagrams will be found in the Tentative Training Manual of the M. T. C.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

M. T. C. OPERATION

LECTURE V

This lecture will embody some of the more important French Auto terms:

ENGLISH.	FRENCH
Axles	Essieux
Front axle	Essieu avant
Rear axle	Essieu arriere
Bearing	Coussinet
Belt	Courroie
Bolt	Boulon
Brakes	Freins
Brush, small	Pinceau
Brush, large	Brosse
Bushing	Bague
Can, gasoline	Bidon
Chain	Chaine
Chisel, cold	Tranche
Clean	Nettoyer
Clutch	Embrayage
Crank (for starting)	Manivelle
Differential	Differentiel
Disassemble	Demonter
Driving	Arbre a cardan
File	Lime
Flange	Aile
Fly-wheel	Volant
Frame (made of pressed steel)	Emboute, acier tole
Gasoline	Essence
Gear Box	Boite de vitesse
Grease	Graisse
Grind	Roder
Hammer	Marteau
Hangers, spring, in front	Mains
Inner tube	Chambre-a-air
Inspect	Verifier
Kerosene	Petrole
Map	Carte
Motor	Moteur
Nail	Clau
Nut	Ecrou
Oil	Hile
Overhauling	Revision
Pliers	Pinces
Repair	Reparer
Replace	Remplacer
Rims, steel (on wheels)	Jantes
Road pass (red)	Permis rouge
Screw	Vis
Screwdriver	Tournevis
Shaft, driving (or connecting)	Abre d'accomplement
Spark	Volonte
Spark Plug	Bougie
Springs	Ressorts
Steel, rolled	Acier Lamine
Steering Gear (hand wheel only)	Direction
Straighten (rods, etc.)	Redresser
Sub-Frame (under motor)	Paux-Chassis
Thread	Filet
Tires	Bandages
Tire, casing	Enveloppe
Tires, solid	Bandages pleines
Tools	Outils
Universal joint	Cardan
Valve	Soupape
Web	Aine
Wheels	Roues
Wire	Fil de fer
Wrench	Clef anglais

Following are some engineering terms which would be useful should you ever proceed to some French Engineering Depot to load up:

ENGLISH.	FRENCH.
Beams, small	Crevrons
Cardboard	Carton groudronne
Cardboard, corrugated	Carton oudule
Cots	Couchettes
Cross pieces	Bastings
Duck walks	Caillebotis
Fascines	Fascines
Frames	Chassis
Laths	Liteaux
Logs	Rondins
Pickets, large wooden	Grands piquets en bois
Planks	Madriers
Planks	Planches
Planks, small	Voliges
Shelters, light	Abric, legeres
Beams, iron	Poutrelles de fer
Frames, folding (for barbed wire)	Chevaux de frise
Mine triangles	Triangles de mine
Pickets, iron	Piquets de fer
Posts, observation (iron)	Guentes en tale
Sheet iron	Toles
Wire, barbed	Reseau brun a picots
Wire, reinforced woven	Grillage protege bombe—renforce

You will come in contact with a great many French officers in your daily work and you must remember that you owe the same respect to the uniform of the French that you do to your own. Among the first things a foreign officer will notice are your salute and bearing; render them the same courtesies that you do to your own officer.

French Army Grades and Ranks

The following are the French army ranks and insignia, infantry, cavalry, artillery and transportation:

RANK IN FRENCH ARMY	CORRESPONDING RANK IN U. S. ARMY	INSIGNIA ON SLEEVE
Soldat	Private	No insignia
Brigadier	Corporal	2 sloping cloth galons
Marechal de logis	Sergeant	1 sloping gold or silver galon
Marechal de logis chef	1st Sergeant	2 sloping gold or silver galons
Adjutant	Sergeant Major	1 gold or silver galon bisected by fine red thread
Sous Lieutenant	2nd Lieutenant	1 gold or silver galon
Lieutenant	1st Lieutenant	2 gold or silver galons
Capitaine	Captain	3 gold or silver galons
Commandant	Major	4 gold or silver galons
Lieut. Colonel	Lieut. Colonel	3 gold galons and 2 silver galons — Infantry and Artillery or 2 gold galons and 3 silver galons — Cavalry and Train
Colonel	Colonel	5 gold or silver galons
General de brigade	Brigadier General	2 silver stars
General de division	Major General	3 silver stars
None at present	General	

Note—Gold galons for infantry and artillery. Silver galons for cavalry and train.

Numbering of Vehicles

The following is the method used in the classification marking and numbering of motor vehicles:

1. System of Classification:

All motor vehicles will be classified according to type as follows:

Passenger cars (regardless of size or body)	Type	1
Light delivery trucks (1 ton or less capacity)	"	2
One and one-half and two-ton trucks	"	3
Three and four-ton trucks	"	4
Five-ton trucks, or over	"	5
Motorcycles (with or without side cars)	"	6
Motor ambulances (all sizes and makes)	"	7
Tractors (except caterpillars)	"	8
Caterpillars	"	9
Trailers (cargo)	"	0
Machine shop trucks (regardless of repair equipment)	"	00
Kitchen trailers	"	10
Omnibus cars	"	20
Balloon winch trucks	"	30
Service cars (light repair)	"	40
Disinfectors and fire engines	"	50
Laboratories (dental trucks, medical laboratories, photo laboratories, sterilizing trucks, etc.)	"	60
Machine shop trailers	"	70

Privately owned motor vehicles, such as the Y. M. C. A., Salvation Army, etc., authorized to procure oil, gas and repairs from official sources, will be given numbers according to the above classification, and in addition the letter X, following the number.

2. System of Marking:

All motor vehicles will be painted with O. D. paint prepared according to government formula. All letters and numbers on motor vehicles will be stenciled with white paint.

Numbers preceded by U. S. shall be stenciled on both sides and rear of each motor vehicle in symbols 4 inches high, excepting trailers and motorcycles.

For trailers, numbers preceded by U. S. shall be stenciled in symbols, minimum of 1 inch in height, on both sides and rear end of the body.

For motorcycles with side cars, numbers preceded by U. S. shall be stenciled in symbols minimum of 1½ inches in height on left of gas tank, rear right side and front of side car.

For motorcycles without side car, numbers preceded by U. S. shall be stenciled in symbols minimum of 1½ inches in height, on both sides of gas tank and on a plate firmly attached to rear mud guard.

3. System of Numbering:

The first numeral will indicate the type. The succeeding numerals will indicate the number of the machine of that type in service in France. (Type 1, machine No. 685, would be U. S. 1685.)

Examples

Machine No. 1, Passenger car, will be	U. S. 11
Machine No. 1, Light delivery truck, will be	U. S. 21
Machine No. 1, One and one-half-ton truck	U. S. 31
Machine No. 5, Private passenger car, will be	U. S. 15X
Machine No. 6, Private 1½-ton truck, will be	U. S. 36X

4. Additional Markings for Motor Vehicles:

In addition to the above, each motor truck shall have the manufacturer's serial number and the motor number stenciled on each side member of the frame of the chassis in a plainly visible location with symbols one inch high.

Each motor truck cover will bear the same U. S. number as the truck to which it belongs. This number will be stenciled in symbols 4 inches high, so as to be plainly visible from the side.

5. Headquarters will be indicated by a metal marker 6 inches by 9 inches, hung on the wind-shield on the right side of the car.

Rank of general officers will be indicated by a metal marker 6 inches by 9 inches hung on the wind-shield on the left side of the car.

These indications will also be displayed on markers of the same size on the rear of the car, in such a position as to be illuminated by the tail light.

6. The cars of the different headquarters will be marked by enameled car markers as follows:

The car of the Commander-in-Chief—the American Flag.
The cars of Staff Officers, headquarters, A. E. F.—red, white and blue.
The cars of an Army Commander and staff—red and white.
The cars of a Corps Commander and staff—white and blue.
The cars of a Division Commander and staff—red.
The cars of a Brigade Commander and staff—blue.
The cars of the Commanding General, Service of Supplies and staff—white.

7. All mixed colors will be divided horizontally.

8. No flags of any kind will be flown from trucks or motorcycles.

Now we come to the map reading for the M. T. C: There are two maps for Motor Transport work, either of which can be purchased in any book store. One is known as the Etats Major, the other is the Michelin Map. Both are excellent and will convey a great deal of beneficial information. They are both sectional and very detailed. The method of representing the different scales is shown herewith.

SCALE

1 cm. equals 800 meters of 1/80,000.
Contours or *Hachures.*
Space between contours equals 20 meters.
Contours short and near together equal steep slope.
Contours long and far apart equal gentle slope.

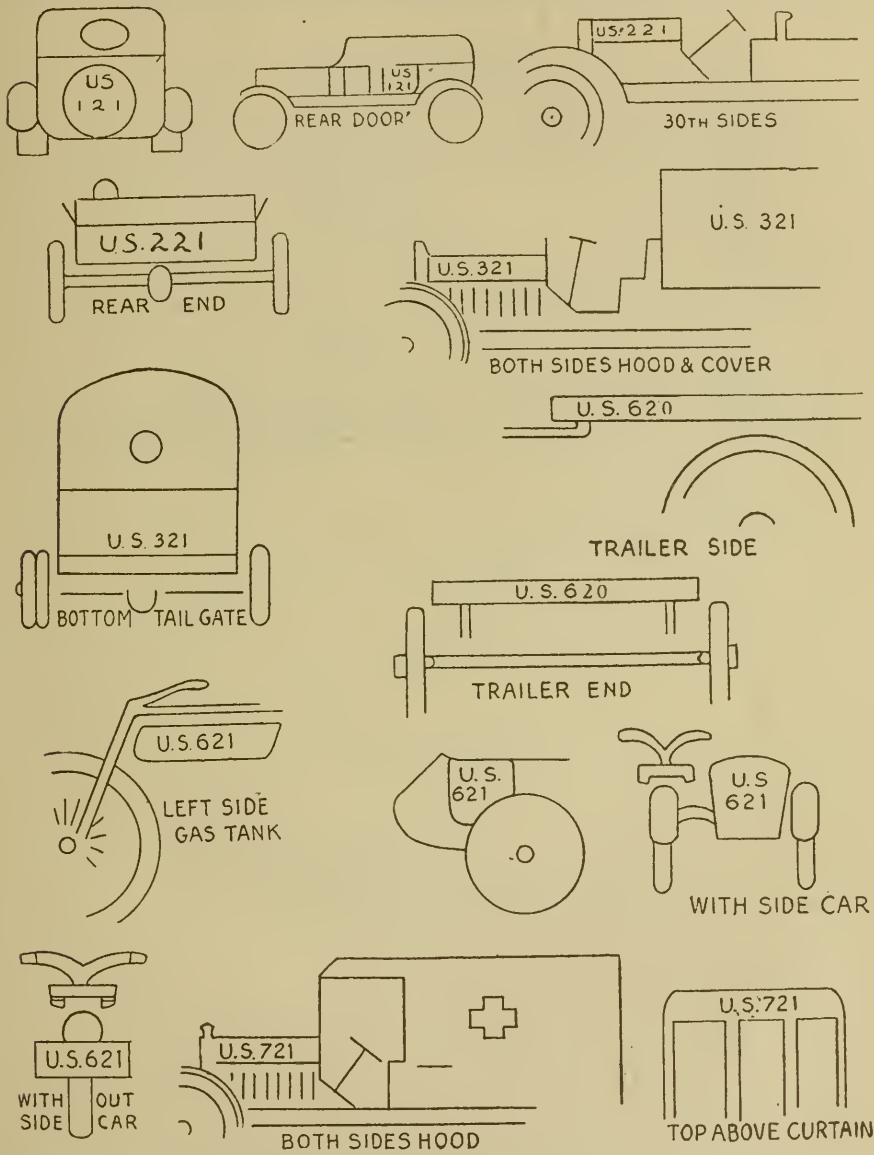
QUICK METHODS OF MEASUREMENT

Use 5 centimes piece—its diameter equals 2 kilometers on Etats Major of 1/80,000.

End of thumb equals 4 kilometers on Etats Major of 1/80,000.

You should know something of the more important measurements regarding distances. Of course the most common term you will come in contact with in France is the kilometer which is ⅝ of our own American mile. If we should say the town of ..... is 50 miles from here, in the French system of measurements we would say the town of ..... is 80 kilometers from here. The next is the meter, which is 3.37 inches longer than our yard.

MANNER OF MARKING M. T. C. VEHICLES



121 shows where numbers are placed on closed and open staff cars.
221 shows where numbers are placed on open body trucks.
321 shows where numbers are placed on cargo trucks, with cover.
621 shows where numbers are placed on motorcycles, with and without side car
620 shows where numbers are placed on truck trailers.
721 shows the position of numbers on Medical Corps trucks.

Following is a table of French and English measurements and their equivalents:

Kilometer	Equals	.625 miles
Meter	"	39.37 in. or 1.0936 yds.
1 inch	"	24.4 mm.
1 mile	"	1,609 meters.
1 sq. meter	"	1,550 sq. in. or 10.76 sq. ft. or 1.196 sq. yds.
1 sq. inch	"	595 sq. mm.
1 cu. meter	"	35.31 cu ft.
1 cu. in.	"	16.39 cu. cm.
1 gal.	"	3.785 litres.
1 litre	"	1.057 qts.

For Quick Computation

1 kilometer	Equals	⅝ miles
1 yard	"	9/10 meter
I livre	"	½ kilogram—1.1 pounds

French time is counted either in two periods of 12 hours each, the same as American time, or in one period of 24 hours, beginning at midnight.

Typical Quiz Questions

1. Show how far the driver is responsible for the loading of his truck.
2. How many commissioned men are there in a Motor Transport Company? What rank are they?
3. What is meant by a Class B truck.
4. Who is in charge of the repair truck?
5. What is the motor equipment of a headquarters motor command?
6. Give two excellent reasons why a convoy should be kept together.
7. When must an order of the military police be obeyed?
8. How long may the motor be allowed to run idle?
9. What is the first thing to do when a vehicle is stopped on a hill?
10. What happens to a driver who doesn't fill in Form MTC-124?
11. What is Form MTC-124?
12. Generally speaking, what is the meaning of "open formation"?
13. Where else in the army have you heard of "open formation"?
14. Name two situations in which trucks are run in "open formation."
15. Being a driver, who is your next superior?
16. What is the rank of your next superior and what does he wear on his sleeves?
17. Who aids you in backing a truck?
18. What two kinds of signals are there?
19. What is the *route gardee?*
20. In what zone is the *route gardee* located?
21. Why must you never "double" another truck or convoy on the *route gardee?*
22. Name two kinds of inspection.
23. Who orders a formal inspection?
24. What tonnage can be carried in a standard AA truck?
25. What truck is the guide truck?

Typical Quiz Questions

1. Name four makes of trucks that may be encountered in the A. E. F.
2. What does the tank truck carry?
3. May a motor truck company be assigned to an Infantry organization?
4. How many vehicles are there in a motor truck company?
5. Who attends to the paper work of a company?
6. In time of war why is it very important to allow none but authorized persons to rid on a vehicle?
7. What is the maximum speed of an ambulance?
8. How many vehicles to a section?
9. What is the rank of a truckmaster?
10. Who keeps the vehicle clean?
11. In making road repairs why is it important to keep a check on the tools taken out of the tool box?
12. If a truck in convoy is about to stop how does the assistant driver notify the truck behind?
13. In what part of company convoy does the repair truck stay?
14. What men are authorized to ride on the repair truck?
15. Who signs for the mechanical equipment of a repair truck?
16. In the temporary absence of the assistant truckmaster, who could and should take his place?
17. In the temporary absence of the assistant mechanic, who can take his place?
18. What truck controls the speed of the convoy?
19. How does this truck control the speed of the convoy? Explain.
20. If by any chance the convoy should be split, what signal should the assistant driver ahead of the split, give?
21. Give the French for any three road signs?
22. What is the least number of vehicles that can be called a convoy?
23. What one thing makes the loading of troops more difficult than the loading of supplies?
24. Are the officers of the Allies entitled to the same courtesies as our own officers?
25. What is a quick way of determining a distance of 2 K (Kilometers) on a French Etat Major Map?

Typical Written Examination Questions

1. Give a brief outline of what you consider the main duties of a Motor Transport Company?
2. Tell some signs that make apparent a poorly loaded truck?
3. If you had to carry typewriters, oil in barrels, and clothing, how would you load?
4. Write out the personnel, both commissioned and enlisted, of a motor transport company?
5. Blanks of Form MTC-124 being provided, fill out with the details of an imaginary accident.
6. Write out the distance between trucks in open and close formation.
7. What is the procedure on approaching, crossing, and leaving a bridge?
8. Write out the six road rules.
9. Write out accurately the French for:
   (*a*) Not permitted.
   (*b*) Railroad.
   (*c*) Turn to the left.
   (*d*) Turn to the right.
10. On what side of town do you unload troops?
11. How would you prepare your truck for a formal inspection?
12. Explain briefly the system adopted by the M. T. C. in marking vehicles?
13. Why is a map necessary in convoy?
14. A distance of 80 miles is how many kilometers?
15. How is French time reckoned?

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

MAINTENANCE

LECTURE 1

TYPES OF MOTOR TRUCKS

Motor Trucks are divided in general into three main types: Four-Wheel-Drive, Two-Wheel-Drive, and the Road Tractor.

The Four-Wheel-Drive, as its name implies, is driven by the application of power to all four of its wheels through shafts from a centrally-located gear box just behind the transmission proper. The chief advantage of this type is that it applies traction to all four of its wheels. Its main disadvantage is the complicated nature of its working parts, and the difficulty of obtaining a satisfactory road clearance, owing to the necessarily low front axle and steering knuckles, a lowness enforced by the drive shaft connections at the front wheels.

By far the great majority of Motor Trucks are of the Two-Wheel-Drive type, the drive being applied to the rear wheels. This type is sub-divided into three kinds of trucks, which take their names from the means of final drive which they employ. They are the Chain Drive, the Internal Gear Drive, and the Worm Drive. Each one of these has its ardent champions in the motor truck industry, although latterly the Chain Drive has been decreasing in popularity, while the two others have been gaining.

The Chain Drive is exactly what it says; power is brought back to two sprockets, which are usually from eighteen inches to two feet in front of the rear wheels, and this power is then transmitted to two or more sprockets on the rear wheels through heavy driving chains. It is the earliest form of drive among trucks, and has the good feature of exerting its pull near the outside of the wheel, rather than at the hub. It is obvious that the farther from the hub and the nearer the outer diameter of the wheel the force is exerted, the greater is the leverage which is brought to bear. However, the Chain Drive adds a number of more or less involved parts to the truck mechanism, and it is doubtful whether this is balanced by the advantages.

The Internal Gear Drive has two cross members in the rear axle, one the supporting axle which carries the weight of the truck, and the other the driving axle which transmits the power from the differential to the rear wheels. This driving axle has spur gears on the outer ends which engage with ring gears on the rear wheels, thereby giving it the increased leverage of the Chain Drive with none of the incumbent noise and multiplicity of wearing parts. It has furthermore the advantage of not having the ring gear at the differential which makes possible a smaller differential housing, and increased road clearance.

The Worm Drive is considered by many as the smoothest and most efficient means of final drive yet devised. In this case the drive shaft is developed at it after end into a screw which engages with a worm gear surrounding the differential. The mechanical principal of the screw is one of the most positive methods known for applying energy, and in the case of the worm truck drive all of its advantages have full scope. The Worm Gear handles its oil on

the principle of the well wheel. If you will remember how the wheel of a well dips down into the water and carries the water up, you can readily grasp how the worm gear dips down into the oil contained in the differential housing, carries this oil up, and spreads it on the worm. The Worm Gear is quieter than either chains or bevel gears.

The Road Tractor, as its name implies, is a tractor designed for hauling over roads, rather than for pulling plows through fields. It is therefore, capable of better speed than a farm tractor, and is not unlike an ordinary motor truck, except that instead of carrying its load in its own body, it has a fifth wheel between the two rear wheels, and to the fifth wheel is attached the trailer in which the actual load is carried. To this first trailer other trailers may be strung, so that the Road Tractor is an elastic unit of large capacity.

General Construction

All motor trucks no matter of what class, have certain features in common. They must be sturdily built throughout, appearance being second to strength in truck design.

The radiator and cooling system of a truck must be of extra large capacity to guard against overheating. A truck engine, owing to the heavy loads it has to haul, is being constantly run for long distances with the transmission in one of the lower gears. This high motor speed has a tendency to heat the engine which only efficient radiation can overcome.

Frame, axles, and steering mechanism of a truck have to be strongly made and especially designed in every detail to take successfully the wear and tear of the constant use and abuse to which they are subjected. The wheels of a truck are in themselves a problem, as here again there must be the maximum of strength.

Truck tires call for a particular type. Easy riding qualities must give way to dependability and long wear so that solid rubber tires are in general use for this service rather than the pneumatics which grace the pleasure car.

Accessories of a truck have to be in the nature of things reduced to the simplest forms, as for instance, the starting and lighting equipment. Elaborate electrical apparatus will not do here, for it must be remembered that the truck driver is seldom the truck owner, and the more fool proof and the less delicate a truck can be in the hands of the usual truck driver, the better it is for all concerned. In spite of the great progress made in electrical equipment for motor vehicles, such equipment is still liable to derangement, and as a consequence, the truck motor is usually started with the familiar hand starting crank. Electric lights are not always found on trucks, as a truck, by reason of its comparatively slow speed has no imperative need for high powered lights, and also because the fine filament in an electric light bulb is readily destroyed by road shocks taken through solid tires.

Truck springs have to be carefully engineered to do their work. Their duty does not call so much for smooth riding as for the ability to resist great overload and sudden strains out of all proportion to the specified capacity of the truck. The commonest fault in all motor truck work is the tendency to overload. A truck driver will usually fill the body with whatever he is to haul regardless of what the material may be. If the truck has the capacity of one ton, and the body is designed to hold a ton of wood, the truck driver, when he is set to hauling iron, will frequently load the body to its full capacity, thus creat-

ing a load of from three to five tons. This is a great mistake, and should never be permitted, as one such load may put the truck out of commission altogether, and will certainly shorten its useful life very appreciably.

In general no other piece of mechanism answers so quickly to good treatment as a motor truck. One vehicle in good hands will outlast ten wrecked by carelessness, not especially the carelessness of a sudden smash-up, but the long-continued carelessness in little things which so quickly saps the life of a truck. For instance, in the one item of lubrication, systematic care will produce splendid results. There are certain parts which must be oiled and greased oftener than others, and a regular schedule should be arranged and followed by which each particular part is cared for at its proper interval of time.

Nomenclature of Parts

The Frame is the first part laid down in truck assembly, and it is the part on which the truck is really built. It consists of the Side Members which run lengthwise, and the Cross Members which hold the side members together.

The Front Axle carries the two Front Wheels, which are mounted on Spindles and swung in either direction by the Steering Gear, permitting the truck to move to the right or left at the will of the driver.

The Radiator is placed crosswise at the front to allow easy access for a plentiful draught of cooling air through it. The radiator consists of an outer Shell surrounding the Core through which the air blows and inside of which the water circulates.

Behind the radiator is the Motor, consisting of Cylinders, Pistons, Connecting Rods, and Crank Shaft. Attached to the motor is the Carburetor for supplying it with a properly mixed gas, and Magneto or Generator by means of which the motor produces the electricity which ignites the gas. Exhaust gases are drawn off through the Exhaust pipe to the Muffler which reduces the noise of the motor's explosion.

The flywheel of the motor is at the rear end, and is hollowed out to receive the clutch, the function of which is to prevent the motor from stalling when the truck stops.

Behind the clutch is the Speed Change Gear Box, by means of which the gear ratio can be increased or decreased by the driver, enabling the truck to start with heavy loads, to climb hills, or accomplish any other especially hard duty.

The Propeller or Drive Shaft conveys the power back from the speed change gear box to the Differential on the rear axle. To understand the action of the differential, just remember how a rank of men behaves when it turns, say, to the right. The right hand man practically stands still and marks time, while the left hand man has to take long steps and hurry to keep up with him. When a truck turns a corner the same thing happens. If the turn is to the right, the right hand wheel goes slow, and the left hand wheel goes fast. If the wheels were on the ends of a solid axle they would soon tear the rear end out of the truck; but the axle is divided by the differential, and this part takes its name from the fact that it supplies a means for taking care of the differential in rear wheel speeds when the truck goes around a corner.

One of the advantages of the worm drive is that it carries the drive shaft back to the rear axle in what is practically a straight line. Bevel gears on the other hand bring about an angle in the drive shaft. There is also a general tendency at all times for the driven parts to get out of a straight line. This irregularity of alignment is taken care of by the Universal Joints, which can transmit power in more than one direction.

The Rear Axle consists of the driving means, either worm or internal gear as already described, the Brake Drums, and the Axle Housing.

The Brake Rigging carries the braking power from the hands or feet of the driver through Brake Rods to the brake drums on the rear axle, or to a brake drum sometimes installed on the drive shaft at the transmission.

The truck Body is placed on the frame behind the Cab, which contains the Seat, the Steering Wheel and Column, the Controls by which the motor is operated, and the Dash upon which are arranged the Instruments for the driver's convenience. On the floor of the cab are the Floorboards, and coming through the floorboards are the Clutch Pedal and the Service Brake Pedal, the Gear Shift Lever, and the Emergency Brake Handle.

For a complete description of motor truck parts, including those of less importance, as well as the main ones, the student is referred to the chart of a truck chassis in the "Standardized Military Truck Class B" Instruction Book.

Strength of Members

As the strength of materials is purely a technical calculation this will be omitted.

Special Features of Standard Trucks

The Government Standard Class B Truck is a fine example of present day motor truck practice. It is of the worm drive type with a four cylinder motor, and the whole truck is the final word in simplicity and solidity of construction.

Other prominent worm drive trucks are the Pierce and the Packard. Quite recently the Maxwell and the Ford Companies have brought out small trucks equipped with worm drives which are cheap and serviceable.

The Republic Motor Truck Company is the largest maker of internal gear drive trucks, while the Denby, and numerous smaller concerns are manufacturing this type.

Chief among the four-wheel-drive makers are the Nash Motors Company of Kenosha, Wis., and the Four Wheel Drive Truck Company of Clintonville, Wis. This type has been rapidly gaining in favor, and has had marked military recognition both on the Mexican border and in France.

It is a notable fact that practically all trucks are equipped with motor governors. This device automatically controls the speed of the motor, preventing the engine from being unduly raced, and at the same time allowing a wide open throttle on a long, hard pull. The governor is sealed by the truck maker, and if the seal is broken the truck is no longer guaranteed, the manufacturer being thus protected against abusive handling by the driver.

LECTURE II

Excessive wear makes is necessary to replace the piston pin and piston-pin bearing. Renewing of the bushings only is often insufficient as the pin is generally worn also. A shoulder on the pin can generally be felt or the wear can be detected by measuring the pin with a micrometer caliper. As a rule the connecting rod bearings and the wrist pin bearing wear more than the main engine bearings and should be examined first.

Difficulty is sometimes experienced in removing piston or wrist pins. This can many times be accomplished by turning down a rod that will slide freely through the bushing and then threading it. Over this is fitted a bushing slightly smaller than the hole in the piston. If the rod is threaded with a standard S. A. E. thread, a standard nut may be used, and by screwing the nut down on the rod the pin may be drawn out. If the piston is aluminum, a wrist pin which seems tight can be loosened by plunging the piston into boiling water, after first having removed the locking device.

Removing piston pin bushings, if they are of the oscillating type, can be accomplished by the same process as mentioned in the removing of wrist pins. A reamer may also be used and the bushing reamed out, if the idea is to renew the bushing. If the bushing is slotted carefully with a hack saw while the piston is held in a vise, it will be easy to drive out.

Removing the bushing in the upper end of the connecting rod is sometimes a difficult task. This can be successfully accomplished in several ways, the most common of which is to open the jaws of a vise far enough so that the end of the connecting rod rests upon them and at the same time gives sufficient clearance for the bushing between as it is driven out. A bar of brass or steel of suitable diameter is used to drive the bushing out.

Another way to remove a connecting rod bushing is to open the jaws of the vise wide enough to admit a piece of pipe slightly longer and larger than the bushing to be removed. The jaws should be opened wide enough to admit further the end of the connecting rod, and a steel bar, the diameter of the hole in the connecting rod and slightly longer than the bushing to be removed. By simply tightening the vise the bushing is forced out by the steel bar into the pipe.

There are few repairs to the crankshaft which the ordinary mechanic can accomplish. When the engine has been taken down, the crankshaft can be measured with micrometer calipers to determine whether any of the pins or journals are worn out of round. A shaft which is worn undersized or out of round can, in the base repair unit, be put in the grinder, all the pins and journals turned up to within ten-thousandth undersized or twenty-thousandth undersized, and new babbitt can be fitted to the engine base, or rod and bearing out of line reamed to fit the shaft. This will be explained later.

Sometimes welding the crankshaft is attempted. In most cases the attempt proves unsuccessful because the metal on both sides of the weld is weakened by being burned and it is almost impossible to weld a shaft so that it will be

true without having a light cut taken off each bearing. If the crank is bent or sprung slightly in service, it may not be visible to the eye except when the shaft is revolving between centers on a lathe with a tool or other object held stationary close to the center bearing. If it is only slightly out of true, proper fitting of the bearing is almost impossible.

A shaft is sometimes straightened between centers in a heavy engine lathe or by being supported by its ends between suitable blocks under an arbor press. It is even possible to improvise a straightening process with timbers or a heavy automobile jack. Assuming that the shaft is bent if it be sprung in the opposite direction with a bar, and while held in that position the center main bearing is struck a sharp blow with a hammer, the bearing surface being first protected by a piece of brass or other available metal, the tendency of the shaft will be to straighten. This operation should not be attempted except in a heavy engine lathe. A suitable block should be procured upon which leverage may be obtained in using the bar. This operation is repeated again and again, a test being made each time the shaft is sprung. In making these tests one should not be misled by a bearing surface of the shaft that is probably worn out of round; the test should be made at the side of the bearing where little or no wear is liable to take place. And even then it is not the best thing for the lathe. In the base plant, if the shaft is bent very badly, it would be turned down to one of the several accepted, undersized dimensions.

A scored crankshaft. When the engine has been disassembled the crankshaft should be examined. If any rings or ridges can be seen or felt, the crankshaft should be held in a vise between grooved, wooden blocks and carefully "emery clothed." To do this properly, some fine emery cloth should be torn into strips about 1½" wide and well oiled and the crank rubbed. Emery tape is better for this work when obtainable. If the emery cloth completely encircles the shaft, and a long steady movement be imparted to it, there will be no tendency to make the shaft oval.

The best alternative is to first file the untrue parts of the shaft with a very smooth file to as accurate a circular shape as is possible, testing frequently with calipers. A lead "lap" is then made in a set of clamps or an old rod and bored out to a size to fit the crank pin. Paper or card shims are inserted between the two halves of the "lap" so that the halves can be gradually closed down by the bolts onto the crankshaft. The "lap" is dressed with fine emery and oil and worked around the crank pin by hand until a good surface is obtained.

A common mistake is an attempt to seat a badly grooved or pitted valve on an equally bad seat, which is an almost hopeless job. It is also useless to use coarse emery and bear down heavily on the grinding tools with a hope of quickly wearing away the rough surface. The use of improper abrasive material is a frequent cause of failure to obtain a satisfactory seat. Valve grinding is not a difficult operation if certain precautions are taken before undertaking the work. The most important of these is to ascertain if the valve head or seat is badly scored or pitted. If such is found to be the case, no ordinary amount of grinding will serve to restore the surfaces. In this event the best thing to do is to remove the valve from its seat and to smooth down both the valve head and the seat before an attempt is made to fit them together by grinding. It is sometimes necessary to have this work done in the machine shop or with special tools designed for the purpose. Another important precaution is to make sure that the head is not warped out of shape or loose on the stem.

Valves need grinding when either the inlet or exhaust valves leak. The exhaust valve has a tendency to leak more than an inlet valve because it is exposed to more heat.

Weak compression generally indicates that the valves are leaking and need to be ground, although a lack of compression may result from leaky or worn piston rings. If the engine has been torn down so that the valves are accessible, a test may be made of them by placing Prussian blue on the face of the valve. Then turn the valve one quarter round in the valve seat. If the seat shows a clear clean line of blue it is a perfect valve. If there are points where the blue does not touch it indicates a worn or warped valve and should be ground.

To test the valve seat, it is merely necessary to reverse the operation, placing the blue upon the seat and revolving the valve head.

It may be necessary in grinding the valves to remove the intake pipe. Remove the valve cover plates and valve cap. If the motor has a removable cylinder head the valves are exposed and are ground into the cylinder casting. The valve springs must be removed and this is accomplished with a valve lifter, care being taken that mashed fingers are not one result of this operation. After the tension is taken from the valve retainers, the locking device may be removed and the spring taken out, allowing the valve to be lifted from its seat and guide. Grinding compounds are made in three grades, coarse, medium and fine. The coarse is usually used first, being placed on the valve head and equally distributed over the valve seating surface. A light spring should be placed under the valve, which will allow the valve to raise from its seat when the weight is taken off of it. The valve is then placed in the valve seat and is, of course, held in place by the valve stem within the guide. A screw driver or valve grinding tool is used and the valve should be turned about a quarter revolution, back and forth in its seat, occasionally lifting it from the seat and shifting it around. Do not turn it round and round. When the pits on the valve are almost removed continue with a finer grinding compound until a perfect seat is obtained. Remove the valve and clean all of the grinding compound from the head and seat, being sure that none of it has worked down to the valve stem into the valve guide. Exceeding care should be taken in cleaning away all of the grinding compound. Too much pressure placed upon the valve grinding tool will cause rings to be cut in the valve or seat. Therefore 3½ lbs. pressure is recommended as sufficient. Tests for a perfect valve seat can be made with Prussian blue as previously described. A valve that is properly seated will bounce back when dropped into its seat. If it stops with a dull thud, either the grinding is not perfect or the valve stem is bent. A test for a perfect seat can also be made by marking the valve head with pencil marks, placed about ¼" apart, and if it is possible to wipe all of these marks away by turning the valve in its seat, a gas tight valve is assured.

In grinding the "cage type" valves the same general method is employed as in grinding the "poppet type" in an "L" or "T" head. The cage is removed, retained in a suitable retainer and the valve ground in the cage.

The angularity of a valve seat should never be less than 45° from the perpendicular. Less than 45° will usually produce a sticking valve.

When new rings are to be fitted in an engine the first operation is to see that the slot is closed when the ring itself is placed in the cylinder without the piston. Should this space be too great the ring is called under-sized and is discarded for another. Should it occur that the ring does not close, a flat mill-file is used to widen the slot until the ring fits the cylinder without a gap. When you see a sleeve which has the three rings in it you will readily note that ring which is correct. The next fitting operation is accomplished with the piston. This consists of placing the ring in the groove so that there is a

snug fit all around. The fitting of the ring being very important, it will be well to note that both of these operations must be executed with care. After fitting the rings to the cylinder and then to the piston we enter into the third and last operation called "lapping in." This is accomplished by placing the connecting rods in the piston, inserting the pin and fastening same. A piece of wood, say two or three feet long, is next placed through the lower bearing of the rod. The grinding element or compound is applied in small quantities around the rings and the entire assembly is placed in the cylinder which is fastened in a horizontal position on the bench. The mechanic now substitutes himself as a crankshaft and by continuously pushing and pulling the piston up and down in the cylinder for an hour or more, a perfect bearing of all the rings upon the walls is developed. It is advisable to place a block of wood in the head of the cylinder before inserting the piston, because when a cylinder is bored, it is not finished any further than the end of its stroke. You will readily see that should the piston be placed in without this block, it would pass into the firing chamber where the top ring would be permitted to expand preventing the pulling out of the piston. This has caused much loss of time as the ring generally must be broken before the piston can be relieved. In placing the cylinder on the piston when a motor is being assembled, the rings are so arranged that the slots are equidistant. Every detail such as has been mentioned is guarded against as neglect in time causes loss of compression. In conclusion, when a piston is of the proper diameter, and the rings fit perfectly, they will only permit sufficient oil for lubricating purposes to pass. It will be seen from this that if the rings fit perfectly and are not in line, carbonization will be almost eliminated.

To test to see if a connecting rod is loose, remove the lower crank case, take hold of the rod and see if there is any play, by a vigorous push up and down. If so the looseness can be felt. Don't mistake the side play, however, for the looseness, as a slight amount of side play is necessary. There may be from 1/64 to 1/16" play of the connecting rod parallel to the length of the pin. There may be as much as 3/16" play of the upper end of the rod along the piston pin or of the piston pin between the bosses.

Connecting rod and main bearings may be adjusted without taking the engine out of the frame. However, this does not hold true where it is impossible to work at the engine from below. The following instructions will give a good idea how to proceed in order to properly adjust the connecting rod and main bearings in many of the modern engines. First—Drain off oil by removing the drain or pipe plugs from the bottom of the oil pan; then place a small lift jack under the pan to keep it from dropping before all of the oil pan bolts or studs that support it have been removed. If there is an oil float in the pan it is advisable to tie it up as high as possible to prevent it from dropping into the oil pan while the latter is being removed. It also makes it easier to replace the pan. Open all of the compression cocks on top of the cylinder. Second—After removing the oil pan it may be necessary to scrape the gasket off the bottom edge of the crank case, and all dirt and dust must be cleaned away so that it will not get into the bearings. Clean hands and tools before working on the bearings and never use any cotton waste or rags which might leave shreds behind as these cause serious trouble to the oiling system. Third—When working on bearings it is a good plan to pull out the piston rings and clean off the rings and piston heads. Always oil the piston rings before replacing the piston. Fourth—In removing the bearing caps a socket wrench should always be used, as open wrenches are apt to destroy the nuts. Care should be exercised not to lose any of the shims or liners

and keep them in place until ready to remove them. Where laminated shims are used to take the loose play out of the bearings, the shims can be peeled off to the amount required to give the proper adjustment—never peel off more of the shim at one time than is necessary. Take out the shims that are necessary, being careful to remove an equal amount of shims on each side of the cap. Before replacing the cap, see that the thin shims are placed between two heavy ones with which the connecting rods are supplied always. Replace the cap and draw it up as tightly as possible, using all four nuts and drawing them up evenly and firmly. After such bearing has been fitted and tested, draw up firmly all nuts, and if it is possible to obtain them, use new cotter pins only. Never back up the nut to insert the cotter pin—always draw up to the next notch and never use wire in the connecting rod nuts as it will interfere with the oiling system. Have the cotter pins well bent apart—so they cannot back out when the engine runs.

Fitting Connecting Rod Bearings.—Remove oil pan and take off the bearing caps and remove piston. Take out bearing cap by removing the screws which hold it in place. The back side of the bearing must have a perfect or snug fit on the connecting rod, otherwise it will be impossible to get a perfect permanent bearing on the crank pin. Fitting the back of the bearing is practically the same as fitting the bearing to the crank pin. Using Prussian blue or red lead in the rod and cap will make possible the finding of the high spots between the cap and the bearings and these high spots must be draw-filed. This can be accomplished by placing the bushing in a vise and drawing the file across its face. No attempt should be made to file in the return stroke.

Adjust the bearing to the crank pin so it can be moved to and fro freely, but at the same time it must not be loose. A very good test for proper tightness can be made by allowing the connecting rod with piston attached to assume an angle of about 45° from perpendicular with the crank shaft and at this angle the weight of the connecting rod and piston should make the bearing turn slightly on the crank pin. Remove the connecting rod and replace the piston in the cylinder giving the bearing the same adjustment as when the piston was out. Then turn the engine over by hand several times to make sure that no binding takes place. Do not be afraid of getting the connecting rod bolts too tight as the shims under the caps will prevent the metal from being drawn into too close contact.

While the camshaft practically gives no trouble there are at times repairs to be made, such as replacing a bearing or lining up a shaft and also the dressing of the teeth on the camshaft gear. In most motors, especially when they are new, gears sometimes are a few thousandths too deep in mesh. This can be remedied by pulling the gear and re-machining it or by mill filling. As this seldom occurs we will not dwell upon it any longer. There are no particular troubles attached to the camshaft, so we will embrace the timing of the shaft.

As a general rule all camshaft gears, when timed by the manufacturers, are marked; however, should it occur that a gear becomes broken in such a way that it were impossible to determine the timing with the gear on the crankshaft, we would have to determine first the firing sequence of the engine. Assuming that this sequence were 1, 3, 4, 2, the next step would be to bring, for convenience we will say piston No. 1, at top dead center on admission stroke. This would mean that the both valves were closed and the piston about to start its power stroke. At this point we turn the flywheel clockwise to approximately 46° before bottom center unless otherwise specified by the flywheel mark. At this point the exhaust valve should start to open.

It can readily be judged by the valve toppet clearance. Assuming that the gear on the inlet camshaft were broken, the procedure is practically the same. as you must determine first the firing sequence in order that the cylinder selected should be on top dead center. Then revolve the flywheel to the point of valve opening and place the gear in mesh. It may also be mentioned in this lecture that back lash is oftentimes present and can only be remedied by setting the crankshaft closer to the gears, bringing the crankshaft gear deeper in mesh with the timing gear, or by replacing the worn gears with new ones.

Engine cylinders are sometimes cooled by air particularly on motorcycles and light weight revolving cylinder airplane engines. Practically all trucks and cars used by the Quartermasters and by the United States Army are water cooled.

Water cooling systems are divided into two classes, the forced circulation and the thermosyphon circulation. The latter is seldom used on trucks. In the thermosyphon system the water which becomes heated in the jackets surrounding the cylinders, since it is lighter than the cold water in the radiator, flows upward into the top of the radiator, and is replaced by cold water which flows from the bottom of the radiator into the jackets. This is exactly the same principle as is employed in circulating water from the back of a stove to the water tank in the hot water system in the kitchen.

In the force system a pump, which may be driven by gear, chain, or belt, draws the water from the bottom of the radiator and forces it through the water jackets around the cylinders and out into the top of the radiator, where it flows down through the radiator and is cooled before reaching the pump again to travel the same path. A fan, which is generally belt driven, is provided to draw the air through the radiator and is necessary to secure sufficient cooling, especially when the truck or car is driven with the wind or when it is operated in low gear.

Proper temperature of cylinders has much to do with efficiency and smoothness of engine operations. If the cylinders are too hot, the engine will pound and the lubrication will not be satisfactory. If the engine is too cold the fuel economy will generally be poor and the engine will not operate smoothly. If the temperature of the water is kept as high as possible without the danger of boiling, better economy and smoother running will result. If, after the engine has made a long hard pull, the radiator is so cool the hand may be placed on top of it without discomfort, it is almost a certain indication that fuel is being wasted.

The monometer or radiator-thermometer is used to indicate the radiator temperature and its purpose is to prevent serious trouble by informing the driver that the water is boiling or that the water is too cool for efficient operation.

A device known as a thermostat is sometimes provided for regulating the temperature of water which circulates around the cylinders. It prevents the water from flowing through the radiator and becoming cooled until the desired temperature has been reached, which it maintains. Sometimes a permanent shutter arrangement or simply a curtain or piece of cardboard is used to cover a portion of the radiator and prevent over-cooling of the engine in cold weather.

The radiator for a truck may be of either honey-comb or tubular construction. The cellular or honey-comb radiator is composed of a great number of cells through which the air is drawn by the fan or the air is pressed through by the speed of the machine. The construction of a honey-comb radiator is

rather delicate, and when such a radiator is used on a truck it is generally supported on special springs to relieve it of part of the road vibration and of some of the twisting action to which it would be subjected.

Tubular radiators may be made with a great number of vertical tubes provided with a series of continuous horizontal fins to increase the cooling effect, or each tube may have independent fins.

Recently a great number of truck manufacturers have adopted radiators built with removable top and bottom plates to permit easy inspection, cleaning and repair.

Care should always be taken to avoid filling the radiator with water which contains too much lime or scale forming matter. Water which produces a thick deposit of lime in the tea kettle will do the same in water jackets and probably in the radiator.

The stuffing boxes or glands on the water pump should be kept properly adjusted, that is, they should be just tight enough to prevent leakage. The grease cups for lubricating the pump shaft should be given proper attention every day.

In winter, unless an anti-freeze solution which has sufficient strength to prevent freezing, is used, special precautions should be taken to prevent freezing up of the cooling system. If plain water is used, it is a very common custom to drain at night and refill in the morning. When a drain cock has been opened, it is generally necessary to run up a wire because it is frequently stopped up with sediment. When the water stops flowing, the wire should be tried again so that the driver is sure that no water remains. On some engines it is necessary to drain at more than one point in the system. Suitable cocks or drain plugs are provided at the bottom of not only the radiator but also the water pump, the lower water pipes and the cylinder jackets. After the draining is completed, it is advisable to run the engine for a few seconds to make sure that the water pump housing is clear.

At the front the drivers have made a practice of cutting off the fuel supply at the main tank, running the engine until the carburetor is dry and then placing one or two kerosene side lamps beneath the hood and blanketing the hood and radiator to prevent danger from frost.

When the weather is below freezing, anti-freeze solutions are often used. Such substances as alcohol, glycerine, calcium-chloride and water, or occasionally kerosene are used.

When a radiator beings steaming in cold weather it is generally an indication that it has frozen and it should be blanketed immediately and the engine allowed to run idle until it is warm throughout the entire face.

Boiling of the radiator is an indication of some form of trouble. This trouble may be due to a great many causes outside of the cooling system. Driving with the spark lever in retarded position (or with the spark advance rod disconnected), or prolonged driving in low gear will generally cause boiling. A mixture entirely too rich or entirely too lean may be the cause of boiling. A loose fan belt, a broken paddle wheel in the water pump, or an insufficient supply of water in the radiator might also cause boiling. Obstructed exhaust pipe, a dirty muffler, improper valve timing, may also have the same effect. In zero weather overheating is generally the result of frozen radiator, frozen water pipes, or an in-operative water pump.

If it is a slight leak the tube can be closed by a pair of pliers; if the seams of the tube open, it will require a section or a new tube. The most delicate repair work in connection with radiators is soldering and one must be quite an

expert to make a satisfactory repair. On the Class "B" Military Truck, if the tubes leak, the cast iron header is removed and the tubes are flanged so they will conform with their seat in the shell casting. In repairing the radiator, as was previously mentioned, it depends entirely upon the nature of the repair; for instance, small white pine plugs may be inserted in the section. When they become water-soaked they expand and choke the leak. In this manner entire sections can be blocked off making a very substantial temporary repair.

Hose connections at times are troublesome. Emergency repairs, from taping the manifold, and then giving it a coat of shellac, down to replacing the hose, do not require very much consideration, as it does not need skilled mechanics to do this. These connections should be thoroughly inspected quite regularly.

In the water pump we sometimes meet with such repairs as broken impellors or gears, sheered shafts and stripped packing gland nuts. In the former cases the shaft gear or impellor must be replaced and its indication is a very hot motor with a remarkably cool radiator, but where the stuffing box nut is damaged it can be temporarily repaired by peening. Should the packing gland require new packing, the nuts are simply backed off, the packing placed around the shaft, so that the packing is wrapped in the same direction that the nut is turned when replaced and tightened up. As we have already mentioned, the tightening of this nut should be just enough to stop the leak. Briefly, we have outlined the general troubles, and the shop practice on this subject will enable you to make these repairs.

The purpose of lubrication is to reduce friction. Friction is the force which retards the movement of one surface upon another. Wherever two materials are rubbed together, the friction between them generates heat. This idea is made a little clearer when it is remembered that the Indians used to rub two sticks together until the friction generated enough heat to cause the sticks to take fire. The same idea applies to metals. No matter how smooth a piece of metal may appear to the unaided eye, if looked at through a microscope, it will appear rough as a file. Naturally, the smoother or more polished the metal is, the less friction will be caused; but no matter how "finished" the metal, friction, heat and wear will take place, unless some lubricant is used to prevent it.

Various systems are used for supplying the parts of the engine with a plentiful supply of oil. These systems may be classified under main headings, namely: Splash systems and Force feed systems: The "Simple Splash" system is obsolete, but will be described as it is the foundation of the circulating splash system.

Simple Splash System.—In this system, the crankcase is filled with oil to such a depth that the bottom end of the connecting rod dips into the oil as it revolves, and splashes the oil to all parts of the crankcase bearings, and the fine spray of "oil-fog" caused by the lower part of the pistons when they are at the bottom of their stroke, is carried up into the cylinders. Thus the entire motor is lubricated by the splash created by the impact of the connecting rod bearings against the oil.

As the oil in the crankcase is used up, more must be added to maintain the proper level. This may be accomplished by pumping it to the crankcase from a supply tank by a hand pump or by pouring oil in the breather pipe (opening in crank-case).

While the simple splash system is quite satisfactory when the engine is level, the great drawback of this system is, that if the motor is inclined, as when the car is going up or down hill, the oil runs to one end of the crank-case or the other, so that there is no oil at the opposite end. Consequently the cylinder and bearings at one end get an over supply of oil, and those at the other, none,

causing these to run dry and burn or seize, if the engine is in an inclined position for too long a time. This condition can be somewhat overcome by dividing the crank-case vertically by "baffle-plates," although this scheme only partly remedies the difficulty. On account of this danger, that all of the bearings will not get a sufficient supply of oil all the time, the simple splash system is now never used on automobiles.

Circulating Splash (Pump Over).—This is a system which works on the *same principle as the simple splash, but has improvements which overcome* the disadvantages of the latter, so that a constant supply of oil is provided for all the connecting rod "scoops." "Oil-scoops" are usually attached to the connecting rod bearing to assist in splashing the oil. These consist simply of a small piece of pipe about an inch long, which is threaded and screwed into the lower bearing cup. One side of the pipe is cut away, so that it has the appearance of a sugar-scoop. The lower crank-case in this system is really divided by an oil "pan," which has depressions, or troughs so arranged that when the pan is placed in the crank-case, these troughs come directly under the connecting rod bearings. A supply of oil is held in the crank-case space beneath this pan. This lower space is called the "Sump" of the motor. An oil pump is used to draw the oil from the sump through pipes to the main crank-shaft bearings. As it overflows from these bearings, it is thrown against the sides of the crank-case by the centrifugal force of the revolving crank-shaft.

Oil "gutters" on the sides of the crank-case, lead the oil down to all the troughs, under the connecting rods, which splash it to all parts of the motor as in the simple splash system. The main improvement of this system over the simple splash is that the troughs under the connecting rods will always have oil flowing into them at all times, no matter at what angle the motor may be, and a constant level of oil for each connecting rod "scoop" is assured. Holes in the "pan" allow the oil to return to the sump.

The pumps are usually either of the "gear type" or the "plunger type." The gear pump consists simply of two spur gears which are "in mesh" with each other, and are turned by a shaft and spiral of bevel gears from the camshaft. As two spur gears turn in a close fitting housing the oil is carried by their teeth. The plunger pump is usually operated by an eccentric on the camshaft, which makes the plunger go up and down. This pump may be regulated by adjusting the length of the plunger, so that it will have a longer or a shorter stroke, and will consequently pump more or less, as desired.

A cork float, together with a vertical wire which acts as a level-gauge is the usual indicator of the amount of oil in the sump or reservoir. The reservoir should always be kept more than two-thirds full. A sight feed is also placed on the dash in front of the driver, so he can actually see the oil running. If the oil stops running through the sight feed, the engine must be stopped at once, and the trouble located. Not enough oil in the crank-case, leaky connection in the oil pipe from the pump to the sight feed, dirt, or faulty pump may be the cause. A fine copper mesh screen is always located where the oil enters the pump, and this screen sometimes becomes clogged with dirt interfering with circulation. The screen usually comes out with the drain plug and should always be cleaned when the oil is changed.

Plain Force Feed System.—In this system, the oil is forced by a pump from the oil sump through tubes to the main crank-shaft bearings and then through ducts drilled through the crank-shaft to the connecting rod bearings. The oil flies from these bearings as they whirl around, and the oil is sprayed to all parts of the motor. This system very seldom uses the splash system in connection with the force feed, although it is sometimes done. In this case the oil

would drip down and run into troughs, where it would be splashed by the connecting rod bearings.

Full Force Feed.—This system uses a plunger-type pump which forces the oil under high pressure to the main bearings. From the main bearings, the oil is forced through the hollow crank-shaft to the connecting rod bearings. A hole is drilled in the crank-pin, and another in the bearing cap, so as the crank revolves, the bearing is not only lubricated itself, but as the two holes come together each revolution, the oil is forced to the piston pin and bearings by a copper tube attached to the connecting rod. The excess oil at the connecting rod bearing is thrown against the side of the crank-case by the centrifugal force of the revolving shaft and splashes in a fine spray all over the interior of the engine.

In the "Pierce-Arrow" and "Packard" Trucks, the oil pressure is adjusted by means of a pressure-relief valve, instead of adjusting the length of the stroke of the oil pump. The pressure relief valve consists simply of a valve located near the pump and strainer, on the side of the crank-case and the only adjustment is by means of a nut increasing or decreasing the spring tension; the greater the tension, the greater the pressure. Instead of a sight-feed on the dash, as in the circulating system, the full force system has a pressure gauge, which should vary anywhere from 5 to 30 lbs. according to the type of pump and speed of motor. Should the gauge show no pressure, the engine should be stopped at once, and the trouble remedied. Too much pressure may indicate a clogged pipe. The pressure may be regulated by adjusting the plunger-pump, as described before, or by adjusting the "spring and ball," if this type is used.

Where the full force feed oiling system is used, the oil in the crank-case should be drained out, and the crank-case washed with kerosene. It should be filled with fresh oil every 500 miles. In other systems, this should be done every 1000 miles.

The process of changing the oil is accomplished as follows: (1) Unscrew drain plug at bottom of oil sump, draining oil into pail or other receptable. (2) Replace drain plug. (3) Pour about a gallon of kerosene into crank-case through the "breather" pipe. (4) Crank the engine for about a minute either by hand or starter. Do not start the motor under its own power. (5) Remove drain plug and allow kerosene to drain out completely. (6) Fill crank-case with fresh oil to the proper level. (7) Crank engine over several times before starting, in order to get the fresh oil into bearings, and started in its proper channels.

Only the best grades of oil should be used in a gasoline engine. The oil should have good cohesion (viscosity) and a high flash-point and fire test in order to give proper lubrication in a motor, for the heat in the cylinders (about 400° F.) will "break-down" or burn up a cheap unstable oil, and an engine can be actually worn out in about 1/3 of its natural life by using poor oil. Follow the recommendations of the manufacturer in the matter of oil, whenever possible.

The use of a poor grade of oil, but especially a lack of sufficient oil will cause all the bearings and pistons to swell, and if allowed to run, the motor will be ruined by burnt out bearings and "scored" cylinders. Lack of sufficient oil can be usually detected by a smell of burnt oil coming from the engine and metallic "knocks."

Unless an engine is new, or has very tight fitting pistons and rings, too much oil in the crank-case will result in an excess of oil working up into the cylinders, past the pistons and into the combustion chamber, where it will be burned, and

leave a carbon deposit. No oil is able to withstand the heat of the combustion chamber, but the poorer the oil, the greater the carbon deposit. If an engine gives trouble by constantly carbonizing and smoking, the trouble may not be too much oil, but leaky pistons and rings. If the oil is kept at the proper level in the crank-case, and the spark plugs are being constantly fouled and oil-caked, and carbon is formed rapidly, and blue oil smoke comes out of the muffler, the trouble may be attributed to leaky piston rings, and perhaps pistons as well. New rings, or rings and pistons should be installed, as the case requires. After an engine has been run many thousand miles, especially if poor oil has been used, the cylinders will be worn oval by the side thrust of the pistons. In this case, the cylinders must be rebored, and over-size pistons fitted, or a new cylinder block and pistons installed. Badly scored cylinders will cause a bad leakage of oil into the combustion chamber. The cure for this trouble is the same as for the oval cylinders, although the use of heavy oil and a teaspoonful of graphite in the crank-case, about every thousand miles will help somewhat.

Motor Truck Company Drivers' Course

MAINTENANCE

LECTURE III

Some knowledge of the proportions of the liquid commonly sold as gasoline will help the understanding of carburetors and of carburetor and engine performance. If a spark plug with two wires attached is suspended in a large-mouthed bottle filled almost to the top with gasoline, a continuous series of sparks can be produced without igniting it. If a few drops of gasoline are shaken in a glass bottle and a spark is produced or a lighted match is held at the neck of the bottle a sudden blue flame or an explosion will occur. If a large mouthed bottle containing a small quantity of gasoline is placed upon an electric hot plate or on an inverted flatiron and heated until the gasoline boils freely, and a spark plug suspended where it is completely surrounded by the warm vapor sparks can be produced without causing any explosion. These tests demonstrate the fact that explosive mixtures must contain both air and the vapor fuel. An explosive mixture can be obtained without reducing the liquid to a clear, transparent vapor by breaking it up into a sufficiently fine spray, for example, like the spray from an atomizer. Even solid fuel if divided into very fine powder mixed with air may be explosive, as is shown by the fact that explosions sometimes occur in the dust laden air in a flour mill or in the coal bunkers in the hold of a ship.

The purpose of the carburetor is to supply a mixture of a finely atomized spray or a vapor of gasoline (or other suitable fuel) and air, in the proper proportion to burn in the cylinder of the engine. Since this mixture must have definite proportions of fuel and air to burn completely, the carburetor must maintain the proper quantity at all times. Too large a proportion of gasoline will result in the escape of some unburned carbon in the cylinder. Too large a proportion of air, on the other hand, will result in some loss of power because the explosions will be weaker. The mixture of about 15 parts of air to one of gasoline by weight, is correct for complete combustion, and should give maximum power. A somewhat leaner mixture will give better economy, but at the same time will give noticeable loss of power. Since it is impracticable to weigh the mixture of fuel and air, the operator adjusts the carburetor according to the behavior of the engine.

As the pistons travel downward in the cylinder on their suction strokes, the air which enters the bottom of the carburetor is drawn through the mixing chamber past the spray nozzle at a velocity so high that it sucks up a spray of gasoline from the tip of the spray nozzle. In the carburetor shown in Fig. 15 the mixing chamber is smaller than the main body of the carburetor so that air will pass through at a high velocity, even when the throttle is nearly closed and the engine is running slowly. The size of the opening in the tip of the nozzle can be adjusted by screwing the needle valve up or down to regulate the proportion of fuel to air. The throttle can be opened or closed to regulate the quantity of charge drawn into the cylinders.

If an engine fitted with this carburetor is primed, started and warmed up, and the throttle is nearly closed in an effort to make the engine run slowly, the quality of mixture, or the proportion of fuel to air can be adjusted by screw-

ing the needle valve up or down. If the needle valve is screwed down too far the engine will miss and "pop back" and if it is set too lean will probably die out entirely. This popping or back-firing takes place because a very lean mixture runs so slowly that there is no fire in the cylinder when the fresh charge comes in at the beginning of the next suction stroke. If the needle valve is opened more the engine will run smoothly when the proportion of fuel to air is somewhere near correct. When it is opened still wider the mixture becomes too rich and the engine runs at a slower speed; if it becomes still richer, the engine will misfire with sooty black smoke issuing from the exhaust pipe and if the priming cup is open the issuing flame will be yellow instead of blue or purple.

The gasoline tank on a motor truck may be located either under the driver's seat or at the dash, the gasoline flowing from it to the carburetor by gravity. In some cases, it is located beneath the rear axle beneath the frame or in some other position so low that either air pressure, or a vacuum tank is required to insure delivery of the fuel to the carburetor, particularly on an up grade or when the tank is nearly empty. Pressure is generally obtained by the use of the hand pump located on the dash. After it has been once established it may be maintained by a pump driven by the engine. The vacuum tank system is very popular with modern manufacturers. It provides an even flow of gasoline at constant pressure to the carburetor.

The principle of the vacuum system is not difficult to understand. The tank is divided into two chambers—upper and lower, the upper one being the compartment in which the gasoline from the tank is first received, the lower one is called the emptying chamber and supplies direct to the carburetor. This lower chamber is exposed to the pressure of the outside air (atmospheric pressure) at all times by means of an open passage leading to the air vent. The upper chamber is connected to the gasoline tank by one pipe, and to the intake manifold by another. The valves are operated by a mechanism connected to the float which operates in the upper chamber. One valve opens and closes the suction pipe to the intake manifold and the other opens and closes the passage to the air vent. If the entire tank is empty, as happens when the tank has just been installed, the float will be at the bottom of the upper tank, and the suction pipe valve will be open and the air vent valve closed. In order to drain the gasoline to the upper chamber, it will be necessary to crank the motor over several times, with the throttle closed, so that nearly all the suction of the pistons will be exerted through the suction pipe, the upper chamber and the fuel pipe. Thus the gasoline will be sucked from the fuel tank to the upper chamber as it will be remembered that when the float is down, the suction valve is open, and the air valve closed. It is sometimes necessary to "prime" the upper chamber with gasoline through the small plug in the top to get the flow of gasoline started. As the gasoline flows into the upper chamber, the float rises, and when the proper level has been obtained a light spring on the float mechanism snaps the suction valve closed, and the air vent valve opens at the same operation. Thus, when the air valve is open the upper chamber is exposed to the open air, just like the lower chamber which is always exposed to it. In other words, both chambers are under atmospheric pressure. A pipe leads from the upper chamber to the lower, at the bottom of which is a "flapper valve." When suction is exerted upon the chamber this valve is "sucked closed," but when both chambers are under the same atmospheric pressure, the weight of the gasoline in the upper chamber forces the valve open, and the gasoline flows to the lower chamber from where it is led through a pipe to the carburetor. As the gasoline runs

out of the upper chamber, the float sinks, the air vent valve is closed and the suction valve opens, and the operation is repeated.

The usual source of trouble in the vacuum system is caused by a pin hole leak in the float, causing it to sink. It may be seen by the diagram that if the float does not rise, the gasoline will fill the upper chamber and be sucked right through the intake manifold into the suction pipe, without going to the carburetor at all. This condition can usually be diagnosed by the evidence of black smoke and explosions from the muffler, and the "checked" action of the motor, which will hardly run at all. If the leak in the float can be found, it should be soldered, but if it cannot be located, a new float must be installed. Those leaks are sometimes so small that it takes several days for the float to become filled and sink and therefore these microscopic holes are difficult to locate. They may often, however, be found as follows: The float which is filled with gasoline by the leak is placed in a dish of very hot water (nearly boiling) so that the water covers the float entirely. The heat of the water vaporizes the gasoline in the float, and expands the vapor, which will escape through the leak and bubble up through the water. The exact spot must be marked. In order to get the gasoline out of the float, it is usually necessary to punch a little larger hole right where the leak is to be repaired, so that the gasoline can run out. Use very little solder, as too much will increase the weight of the float, to an extent that it may not operate properly.

Other troubles usually compromise the "sticking" of some part of the valve mechanism, or the "sticking" of the "flapper" valve between the chambers. Those parts may be inspected by removing the cover of the tank.

On almost every truck there is a suitable shut-off cock beneath each fuel tank and with it there is generally some form of trap to catch the water with a screen or strainer to hold back any dirt or foreign matter that might obstruct the gasoline line or the small passages in the carburetors. The driver should be familiar with this shut-off in order that he may turn it off instantly in case of fire. It is advisable to open at least once a week the drain cock which is provided at the bottom of this trap to allow any water or sediment to escape. The arrangement of the tank is generally such that an emergency supply of fuel will be available by turning the shut-off cock to a different position, or changing from the main to a reserve supply. The fuel line, usually a brass or copper tube, should be so screwed that it cannot vibrate and wear through or break loose at the fittings.

When the speed of the engine increases, and the suction of the intake becomes greater, too much gasoline with relation to the amount of air is liable to be drawn into the mixing of the chamber. In view of this fact, various appliances and principles are used to compensate this tendency toward an overrich mixture at higher speed. In this connection the first that may be mentioned is "Air Valve Compensation." In this case a secondary or auxiliary valve under spring tension is opened more and more, as the speed and suction increase. The spring referred to is usually conical in shape so that the large turns of the coil give a light tension while the smaller turns give a greater tension, as the spring is compressed more.

With such a carburetor, after the engine is warmed and the throttle is set nearly closed the needle valve can be adjusted to secure the correct quality of mixture for running slowly. The speed adjustment is made by changing the tension of the adjusting spring so that the engine will respond properly when the throttle is opened without back-firing and without pouring forth black smoke. The leanest adjustment which will allow satisfactory acceleration is to be preferred. On some carburetors the auxiliary air valve may be a

single weighted valve or a series of balls held closely by gravity and opened by suction at high speed.

Toward the improvement of the air valve form of carburetor much inventive genius has been directed. This is illustrated by the many contrivances, mostly mechanical, each of which has some definite effect either desirable or otherwise. Among these may be mentioned:

A. Interconnection of the air valve with the needle valve or metering pin which controls the main jet.

B. Interconnection of the throttle with the needle valve or metering pin which controls the main fuel jet.

C. Plain secondary jet to supply gas, in addition to that supplied by the main jet.

D. Interconnection of the throttle with the mechanically controlled air valves.

E. Interconnection of the air valve with the needle valve or metering pin to control the secondary jet.

F. Interconnection of the spring controlled air valve with the dash pot which might be made to work in air or gasoline.

G. A gasoline pumping device to enrich the mixture when the engine is to be accelerated.

H. An accelerating well or small chamber containing gasoline which is sucked up suddenly when the engine speeds up.

I. Weighted or loaded auxiliary air valve.

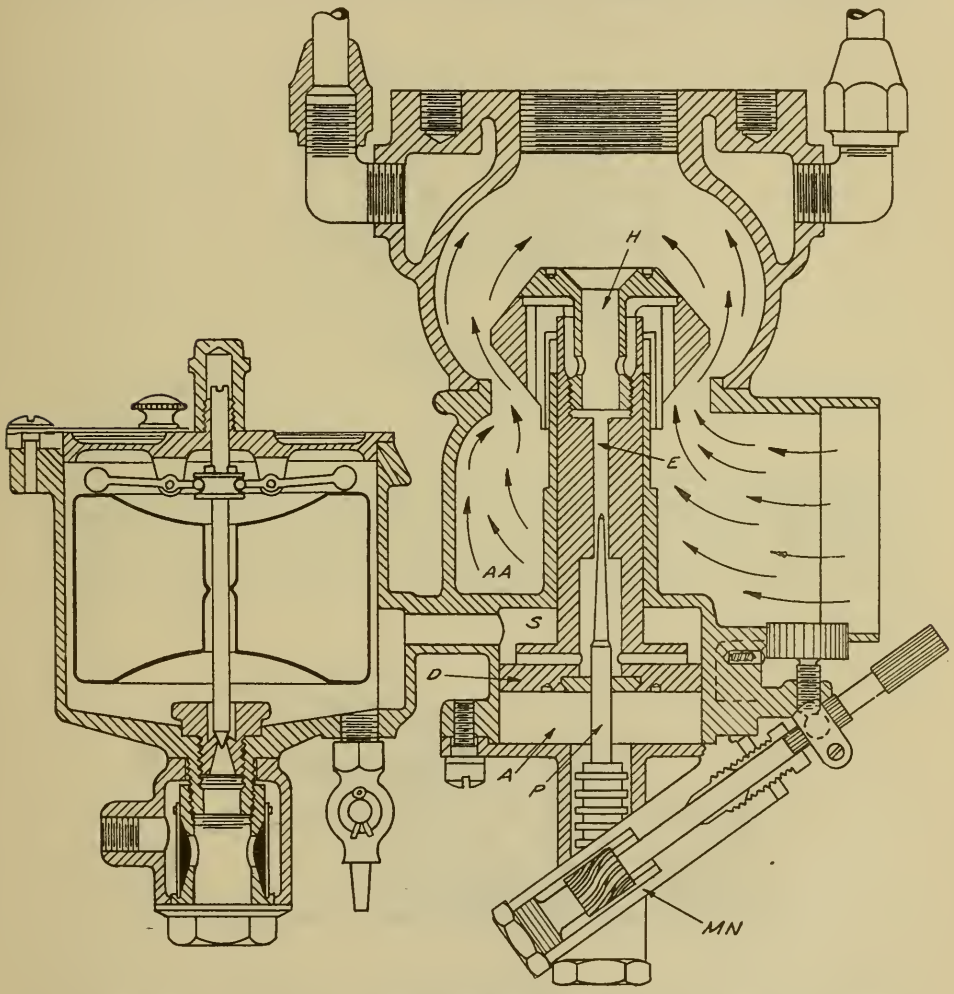
J. The by-pass behind the throttle or under the edge of the throttle to insure the mixture for running idle or slowly. This may or may not be adjustable. It is found on most modern carburetors. These will be discussed later.

It is beyond the scope of this lecture to go into any extended explanation of the advantages and disadvantages of these numerous mechanical devices. It is sufficient to state that mechanical complication in the carburetor is unnecessary and in some cases undesirable. Foreign experience has taught us that carburetors free from mechanical complication and moving parts generally give the best service under the conditions under which military trucks are operated.

With an understanding of the operation of the elementary form of air valve carburetor, the driver or mechanic should be able, by studying the illustrations and directions in the manufacturer's instruction book, to make the necessary adjustments on the carburetor which is more complicated in construction.

There is another way of compensating for the tendency of the mixture from the mixing chamber with a simple spray nozzle to become too rich at high speed and too thin at low speed. This is by regulating the flow of fuel instead of adding air by means of an air valve. There are two methods of accomplishing this result. These have worked out successfully on carburetors which are used extensively on motor trucks. One is to set the quality of the mixture approximately correct for high speed and wide open throttle conditions, and then add gasoline to it to keep the mixture from becoming thin at low speed; the other way is to set the mixture right at low speed and in some way so control the supply as to prevent the mixture from becoming too rich at high speed or wide open throttle.

In the Stewart carburetor the size of the primary fuel orifice is increased as the auxiliary is admitted. The primary air supply enters at "AA" and passes through drilled holes "HH," past spray nozzle located in mixing chamber at "E." Gasoline from the float chamber comes through passages "SS," past needle valve of metering pin "P," through spray nozzle at "E," from which it mixes with the air to form a fine spray. Whenever the motor requires more mixture than can be supplied to passages "H" and mixing chamber "E," the suction lifts the whole air valve "A," which is a free fit in guide



Stewart Carburetor

"K," off of its seat at "I," thereby admitting more air. As air valve "A" lifts away from tapered metering pin "P," a larger quantity of gasoline is drawn up through the nozzle, thereby maintaining the desired quality of mixture. To the lower end of air valve "A," is attached a disk "D," which is submerged

in gasoline and acts as a dash pot to prevent fluttering or too sudden opening of the air valve. To afford easy means of changing the quality of mixture the height of needle "P" can be changed by a rack and pinion "MN," controlled from the driver's seat by a suitable rod and lever mechanism. With this the driver can secure richer mixture for starting and can thin it out as the motor warms up. The taper of the pin and the weight of the valve are determined experimentally by the manufacturer and cannot be improved upon by one who is not an expert.

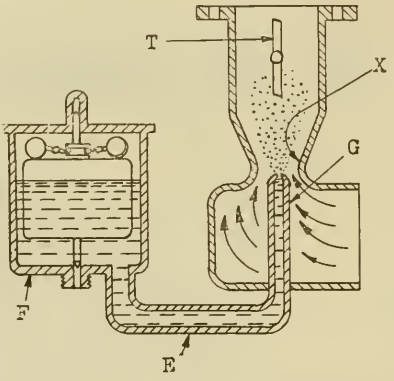


Fig. No. 3

The principle of compensation by use of compound nozzle and gravity fed well (Zenith Carburetor) is illustrated in figures 3, 4, 5, and 6. Figure 3 represents a simple nozzle and mixing chamber, the mixture from which as is already explained, tends to become too rich at high and too thin at low speed. Figure 4 represents two glasses of water arranged with straws; the

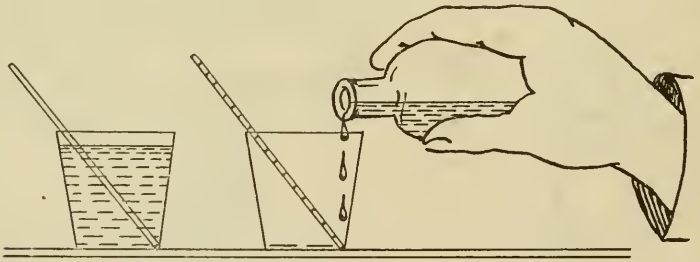


Fig. No. 4

harder one sucks on the straw on the left hand glass of soda water, the more liquid he will get. No matter how hard one sucks on the straw on the right hand glass he cannot draw the liquid any faster than it is poured into the glass from the bottle. The harder he sucks the more air he gets with the liquid.

Fig. 5 represents the application of this principle to the carburetor construction. The liquid flows from the hole I into the well J. While the engine is running the suction draws the liquid out of the bottom of this well as fast as it runs in. The nozzle delivers a mixture of gasoline and air instead of a solid stream of gasoline. With the increase of air velocity there can be no increase in the quantity of fuel delivered up from the nozzle beyond the rate

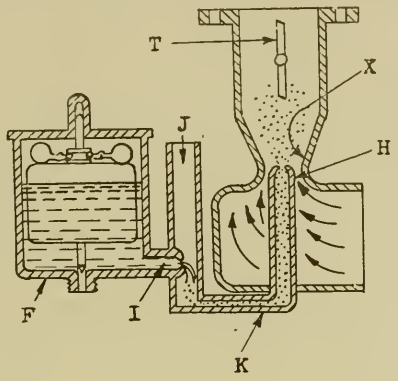


Fig. No. 5

at which it flows into the well J. The quality of this mixture, therefore, becomes leaner and leaner as the quantity of air flowing through the mixing chamber increases.

Figure 6 represents the combination of the two to form which is termed a compound nozzle. The tendency of one nozzle to supply a mixture which becomes lean as the speed increases counteracts the tendency of the other to

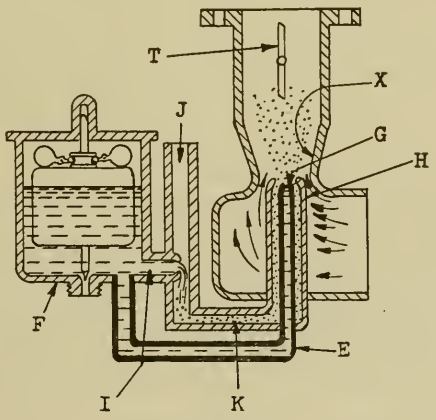


Fig. No. 6

supply a mixture which becomes rich as the speed increases. The result is a practically uniform mixture under all conditions of load and speed.

When the engine stands idle the well J and the nozzle are filled with gasoline almost to the height of the tip of the spring nozzle. When the engine is

cranked this extra supply drawn from the well gives a slightly richer mixture at the start, which is especially desirable. A more complete explanation of the actual construction of a carburetor of this type, with full instructions, can be found in the instruction book issued by the manufacturer of a car or of the carburetor. Carburetors of this type are extensively used in France and in America both on motor trucks and on airplanes. Being free from moving parts they give a very little trouble and require practically no change of adjustment with moderate change of altitude or climatic conditions, a condition not true of a carburetor with air valve compensation.

The new Stromberg carburetor—used on Liberty trucks—embodies several of the features of the Zenith, but does not use a compound nozzle. Instead, it has what is called an "Air-Bled Nozzle." The principle of the air-bled nozzle type will be drawn upon the blackboard. Gasoline flows through a hole which is controlled by a needle, through the passage into the well. When the engine is started the air drawn through the larger venturi creates a very high suction at the smallest venturi. This suction draws gasoline through the small drilled holes at the throat of the venturi, through the vertical tube in the lower end of which is a small hole at the bottom of the well.

As the suction becomes higher and higher, due to the larger amount of gasoline drawn, the depth of the gasoline in the well is lowered. As it is lowered a series of drilled holes are uncovered successively. More and more air is drawn through the "air-bleeder" and through the holes and mixes with the gasoline in the tube, thereby maintaining a correct proportion of fuel to air in the carburetor. The proper size of the bleeder and the sizes of the holes have been determined by the manufacturer and require no change. The quality of the mixture is regulated by the needle valve.

In plain tub carburetors, equipped with the compound nozzle fitted with a gravity well (Zenith), plain tube carburetor fitted with air-bled nozzle (Stromberg, Holly, etc.), the air velocity through the mixing chamber when the engine is running idle causes insufficient suction to lift the gasoline from the nozzle and produce a mixture. To allow smooth running when idle and at low speed, a by-pass tube or feed behind the throttle is generally provided, and is arranged with an adjusting screw, by means of which the quality of the mixture produced and fed in at, or just above the edge of the throttle, can be regulated. This is called the low speed for idle adjustment needle. The majority of air valve carburetors are fitted with a similar tube. Generally in this case the by-pass is not adjustable.

The throttle arm on every carburetor is provided with an adjustable stop screw so that when the throttle control lever on the steering wheel is placed in closed position, the throttle will be held open just far enough to allow the motor to run idle at a slow rate of speed without danger of stopping.

Many devices are used in connection with gasoline engines to make starting easier and to permit regulation of the quality of the mixture from the driving seat. A flooding device, known sometimes as a priming pin or tickler, is sometimes arranged so that the float may be held down until the float chamber is full and gasoline runs out of the spray nozzle into the mixing chamber and the lower air passage.

A priming or fuel pump is sometimes arranged so that the stroke of the plunger will inject a small stream of gasoline or spray of gasoline into the inlet manifold, or sometimes into the valve ports of the cylinder casting.

A butterfly valve sometimes called a choker or strangler is sometimes provided so that when it is closed it shuts off part or most of the air entering

the carburetor. This insures higher suction and a richer mixture when the engine is cranked. This may be connected with the steering column or dash, so that the driver may use it to regulate the quality of the mixture when the engine is warming up as well as to make starting easier.

A dash control may be provided for the needle valve or metering pin (or sometimes for the air valve spring) so that the driver may enrich the quality of mixture to make starting easier while the engine is warming up.

On most engines the air is heated by being passed through a stove clamped to the exhaust pipe before it enters the carburetor. On some other engines, more heat is applied to the mixture at the carburetor or in the manifold after it leaves the carburetor. A few years ago it was a common practice to water-jacket the mixing chamber and the carburetor, and sometimes the intake manifold as well. In some modern designs the intake manifold is fitted into the inside of the cylinder block, and being surrounded with hot water is kept comparatively warm. On a great many modern engines that portion of the inlet manifold directly above the vertical type carburetor, where the mixture must take its first turn to go into the horizontal part of the manifold, is surrounded with a jacket fed with hot exhaust gases, from the engine. This "hot spot" gives very satisfactory results, except that some trouble is experienced due to clogging of the jacket and passages with carbon and oily soot. A few designers have cast the exhaust and inlet manifold in one piece.

The disassembling of the carburetor, cleaning the parts and re-assembling it and making adjustments is work which can be done to much better advantage by a mechanic or one thoroughly familiar with carburetor construction than by the driver. When an engine stops entirely, the driver should NOT take that as an indication that it is time to remove and disassemble the carburetor, but should first be sure that there is a supply of fuel in the float bowl and that there is fuel in the cylinders he should next prime the engine and attempt to start it. If the engine runs for a few seconds and stops it is generally a fair indication that the ignition system is in order. If the engine will not start after it is primed, attention should be directed to the ignition system to determine whether there is a good spark in each cylinder at the proper time. With or without the carburetor, the engine should start if the ignition system is in order, and the cylinders primed sparingly and not warm and flooded with an excess of fuel.

CAPACITY OF A BATTERY

The amount of current that a cell will produce on discharge is known as its capacity, and is measured in ampere hours. It is impossible to discharge from the cell as much current as was needed to charge it, the efficiency of the average cell of modern type when in good condition being 80 to 85 per cent., or possibly a little higher when at its best, which is after five or six discharges. In other words if 100 ampere hours are required to charge a battery, only 80 to 85 ampere hours can be discharged from it. This ampere hours capacity of the cell depends upon the area of the plate and the number of plates in the cell.

The capacity of the cell as thus expressed in ampere hours is based on its normal discharge rate or on a lower rate, for example: Take a hundred ampere hour battery; such a battery will produce current at the rate of one ampere for practically one hundred hours, two amperes for fifty hours, or five amperes for twenty hours, but as the discharge rate is increased beyond a certain point, the capacity of the battery falls off. The battery in question

would not produce 50 amperes of current for two hours. This is because of the fact that the heavy discharge produces lead sulphate so rapidly and in such large quantities that it quickly fills the pores of the active material, and prevents further access of the acid to it, thus while it will not produce 50 amperes of current for two hours on continuous discharge, it will be capable of a discharge as great or greater than this by considerable if allowed periods of rest between. When an open circuit the storage battery recuprates very rapidly. It is for this reason that when trying to start, the switch should never be kept closed for more than a few seconds at a time. Ten trials of ten seconds each with half minute interval between them will exhaust the battery less than will spinning the motor steadily for a minute and forty seconds.

The magnetism from a horse-shoe magnet is called natural or permanent magnetism, but magnetism may be produced by passing a current through a coil of wire wound around a soft iron core. The core is magnetized, one end being the North and the other the South pole. As soon as the current stops, the magnetism ceases. Thus an Electro-Magnet is a magnet only while the current is being passed through the coil of wire around the iron core. It has just been shown that the current flowing through a coil of wire affects the iron bar within it, so as to make the bar become a magnet. These same lines of force that will make a magnet out of a piece of soft iron will set up another current of electricity in another wire close to it, but which has no electrical connection with it, that is, if we make a coil of wire and attach the end of it to a battery and then wind another coil around the first one and insulate it from the first, we would find that every time the current in the first coil (the primary connected with the battery), is started or stopped (made or broken), there is a current set up or induced in the other, or secondary coil. As long as the current in the primary coil continues without change or interruption, there will be no current induced in the secondary winding. The current is produced in the secondary winding only when the flow of current in the primary winding is started or stopped. The effect of the primary coil upon the secondary has been found to be increased by placing a soft iron bar inside the two coils.

The primary winding, as has been noted before, has only about one hundred turns of coarse insulated wire, but the secondary winding usually has several thousand turns of very fine wire. The greater the number of turns of wire in the secondary winding, the higher the voltage. Thus, if a current of six volts is passed through an induction coil which has about one hundred turns of wire in the primary winding and about 10,000 turns in the secondary winding, a current with a pressure of approximately 8,000 volts, but practically no amperage will be induced in the secondary winding.

As the secondary current only flows when the primary current begins to flow and is suddenly interrupted, some device must be introduced which will accomplish this. An "Interrupter" which may be either an electro-magnetic "vibrator" or a mechanical circuit-breaker may be used. The vibrator type is practically confined to use on the Ford car and will not be described at length. Its action is exactly like that of an electric door bell. The mechanical interrupter is used on all low and high tension magnetos and on all battery systems, such as the Delco. In a magneto, this "contact-breaker" is carried on the end of the armature shaft.

The explanation of how the secondary high tension current has been generated has been given, and it now only remains to be explained how this high tension current is distributed to the four spark plugs of a four cylinder engine in succession.

HIGH TENSION MAGNETOS

The high tension magneto combines all the elements of a complete ignition system. It performs three separate operations as follows: It generates a low tension current; it transforms the low tension current into a high tension current; and it distributes the high tension current to the spark plugs. The high tension magneto differs from the low tension in only a few particulars.

The armature on a high tension magneto has not only the primary winding but also another winding, consisting of several thousand turns of very fine wire wound around the outside of the primary winding and insulated from it. As the primary current is interrupted by the breaker points a high tension current is induced in the secondary winding. The secondary current is conducted from the winding through an insulated ring on the armature to a carbon brush and from there to the central point of the distributor. The rest of the magneto is essentially the same as has been described in the preceding lecture.

Two features are included in the High Tension magneto, however, which do not appear in the Low Tension, but which are found on many induction coils. These are the *Condenser* and the *Safety Spark Cap.*

When the two contact points of the "breaker" are suddenly separated there is a tendency for the primary current to continue to flow across the gap. This would cause a hot spark to be formed between the points which would not only burn the points away rapidly but would also prevent a rapid cessation of the current. As the primary current must be broken suddenly in order to get a strong secondary current, a condenser is used to overcome this tendency to flash across the points. In the Bosch magneto the condenser is placed in the hollow of the armature end cover at the circuit breaker end. This condenser consists of two sets of tinfoil sheets, the sheets opposite of sets alternating with one another. They are separated by sheets of mica to insulate them from each other. All the sheets of each set are metallically connected to the conductor leading from the primary winding to the stationary breaker points, while the other set is grounded. In other words, the condenser is "shunted" across the breaker points. The action of the condenser is to absorb the excess current that tends to flow or spark across the points after they are separated.

This is practically a safety valve for the high tension current. It consists simply of two copper points with a rather wide gap (considerably wider than a spark plug gap) between them. One of these points is connected to the high tension or secondary circuit and the other to the ground. If one or more of the wires in the secondary circuit becomes detached, such as a wire to a spark plug, and the secondary current has no place to go, it will jump across the points of the safety spark gap, to the ground instead of jumping through the armature and burning it out as it probably would if no outlet were provided for it.

It is necessary to be able to stop the magneto from producing sparks when it is desired to stop the engine. For this purpose a sheet metal strip is provided which makes contact with the stationary contact point in the circuit breaker and leads to a binding post on the circuit breaker housing. From this binding post a wire goes to a switch on the dash. One side of this switch is grounded. When the switch is closed, the primary current flows from the stationary contact point, through the metal strip, binding post, and wire, through the switch to the ground. In other words, the breaker points are "cut-out" and the primary current is allowed to flow to the ground unbroken.

Consequently, no secondary current is induced and there is no spark at the plugs.

The combustion should take place as the piston is on top of the compression stroke because at that point the gas drawn into the cylinder has been forced up into the head of the cylinder and is at the point of greatest compression—hence more force will be exerted on the head of the piston when the explosion occurs. If the explosion occurs after the piston has started down the pressure is not so great. If the engine is running slowly, the explosion occurring before the top of the stroke, will cause the force to be exerted against the piston travel, and will cause knock and loss of power.

As gasoline vapor requires a fraction of a second in which to explode, there is a difference of time between the time the spark is made at the spark plug and the time of the combustion of the gas actually takes place. If combustion took place immediately, when the spark occurred, then the proper time to set the spark would be on top of the compression stroke, but on account of the rapidity of the piston strokes, we must make allowance for the time necessary for the gasoline vapor to expand, and cause the spark to occur a fraction of a second early in order to have combustion take place exactly on top of the compression stroke. Setting the time of the spark to occur before the top of the compression stroke is called "advancing" the spark. Setting it to occur exactly on top or a little after the top is called "retarding" the spark. It will be understood that when the engine is running slowly the spark should occur in the retarded position, but when running at high speed in the advanced position.

In order to control the position or time, of the spark with relation to the stroke of the piston, the circuit breaker housing is so arranged that it can be rocked around its axle, being provided with a lever arm for the purpose, from which connection can be made to a spark lever on the steering post. It will be clear that if the armature shaft turns right handed and the circuit breaker housing is moved to a certain angle in a right hand direction, the cam will raise the movable breaker point later with relation to the position of the engine crank shaft; while if it is moved in a left hand direction the breaker point will open earlier. In this way the point at which the spark occurs can be shifted through an angle of about 35 degrees.

In general it is customary in installing a magneto to see the spark at full retard with the piston at the top of the compression stroke and the operation is accomplished as follows:

By sticking a long piece of wire through the pet cock of No. 1 cylinder and turning the engine over by hand, the highest point of the stroke may be noted. Both exhaust and inlet valves will be closed. Turn the breaker box housing on the magneto to the full retard position. Then revolve the armature to the point where the distributor brush is making contact with the terminal leading to No. 1 spark plug and the breaker cam is just beginning to separate the points, then either connect the magneto to the shaft or mesh the timing gears as the case may be. Instructions of different manufacturers will vary in this point.

The spark is usually advanced and retarded by means of a hand lever on the steering column, but it may be automatically advanced and retarded as in the Eisemann magneto. The spark is automatically advanced as the speed of the engine is increased by means of a sort of governor on the armature shaft which rotates the breaker housing just as if it were done by hand. This is called a "set" spark.

If no spark occurs at the plug the magneto trouble may be:

1. In the breaker box.

(*a*) Breaker bar spring weak or broken or bar stuck.
(*b*) Points too far apart or too close.
(*c*) Points badly burned or pitted.
(*d*) Short circuit in primary current.

2. In the distributor.

(*a*) Distributor brush not rotating.
(*b*) Distributor brush broken or stuck.
(*c*) Distributor brush oil soaked or glazed.
(*d*) Short circuit in distributor box.

3. The magnetism may be weak in the magnets.

Naturally, before looking for these various troubles it should be ascertained that all wires have tight connections and are not broken.

If the breaker points have too small or too wide a gap they may be adjusted by means of a small wrench and gauge provided by the manufacturer. If they are dirty or sticking, they should be cleaned by means of a strip of fine emery cloth or a watchmaker's file in order to have a perfectly flat, smooth surface. In case the magnets are demagnetized, they should be turned over to the electrician for recharging. When a magnet is fully charged it should lift an iron weight of about ten to fifteen pounds. The magnet is re-charged by placing it on the poles of an electro-magnet, North pole of magnet to South pole of electro-magnet. This operation requires usually about one minute.

All the foregoing has been a description of the armature type of magneto. The Dixie magneto as used on Liberty trucks is of another type known as the inductor type. The general principles of this type are the same, but the rotating element simply has two cast iron inductors which revolve past a stationary armature winding.

The advantages of this type of magneto, as claimed by the manufacturer, are as follows: As the contact breaker box is attached to the mounting of the coil, the latter moves with it when the former is partly rotated to advance or retard the occurrence of the spark in the cylinders, so that the opening of the contact points always takes place at the point of maximum current. An absolute advance of thirty degrees or more is obtained by simply rotating the coil carrying structure to which the breaker box is attached around the axis of the rotating pole pieces.

Inasmuch as the only rotating elements of the Dixie magneto are the two pole pieces there are no rotating wires to cause trouble by becoming unattached. Another great difference between the Mason principle on which the Dixie operates and the armature type is in the fact that the rotating poles in the Dixie do not reverse their polarity at any time, consequently the lag due to the magnetic reluctance in this part is eliminated.

In the discussion of battery ignition the Delco system will be used to illustrate the general principles as the basic principles of all other battery ignition systems are practically the same.

The principal parts of a battery ignition system are a distributor and timer, ignition or high tension coil, spark plugs and wiring, the current being furnished by the battery and generator. The circuit breaker, ammeter, automatic spark advance and combination switch are units that are essential to the perfect operation of the system but cannot be included in the list of principal parts.

In the Delco, as well as in other types of battery ignition systems, the battery is the primary source of electrical current. However, the generator and storage battery are so wired that, when the amount of current generated by

the generator is greater than that generated by the storage battery, the current from the generator not only charges the storage battery, but is used as the source of electrical current for ignition. Therefore the voltage of the primary ignition circuit never falls below the voltage of the storage battery no matter what the speed of the generator may be, and as the voltage or charging rate is regulated in the generator it never reaches a high voltage that would be destructive to the ignition system.

The electrical current which is furnished by the battery and generator is a primary current, so it is necessary to "step it up" to a much higher voltage in order that it will make a spark at the spark plugs. This is accomplished by an ignition or high tension coil, which has been fully explained in a preceding lecture. The only part of the coil that need be considered here is the addition of a resistance unit that is installed with the coil. The purpose of this resistance unit is to obtain a more nearly uniform current through the primary windings of the coil at the time the contact points open. It consists of a number of turns of iron wire, the resistance of which is considerably more than the resistance of the primary windings of the ignition coil. If the ignition resistance unit was not in the circuit and the coil was so constructed as to give the proper spark at high speeds, the primary current at low speeds would be several times its normal volume with serious results to the timer contacts. At low speed the resistance of the unit increases due to the slight increase of current heating the resistance wire.

The timer or interrupter in the Delco system is mounted directly under the distributor and is driven by the same shaft. Its purpose is the same as in the high tension magneto to open and close the primary circuit and by doing so to induct a secondary current in the secondary winding of the high tension coil.

From the high tension coil the current is carried to the rotor of the distributor and there distributed to the various spark plugs. In the end of the rotor arm will be found a rotor or contact button which is held in contact with the distributor head by a spring and as it revolves makes contact with the terminals leading to the spark plugs. The distributor head itself may cause trouble if the track over which the rotor operates gets sufficiently dirty to carbonize so that the spark jumps across one terminal to another and causes premature ignition. The most satisfactory test for a trouble is to replace the head with another head of similar model and note the effect upon the ignition. The track of the distributor head should be kept clean with a rag slightly moistened with gasoline, so as to keep it polished and prevent the rotor button from sticking and thus cutting a track. If a track is cut the rotor button should be inspected to see if it is properly seating and that the spring tension is not too great.

The ammeter is located on the dash of an automobile. Its purpose is to indicate the current that is going to or coming from the storage battery. When the engine is not running and the current is being used for the lights the ammeter shows the amount of current that is being used and the ammeter hands point to the discharge side, as the current is being discharged from the battery. When the engine is running about generating speed and no current is being used for lights or horn, the ammeter will show the charge. This is the amount of current that is being charged into the battery. However, on some systems, such as the Westinghouse as used on the Pierce-Arrow, the ammeter will show very little charge if the battery is nearly at full charge, while, if the battery is low, the ammeter hand will indicate a heavy charge. Therefore, if the ammeter does not show a heavy charging rate from the generator, the conclusion must not be reached that the generator is not properly operating. A hydrometer test should be made of the battery in this instance.

The automatic spark advance is a feature that has been brought out by several manufacturers of battery ignition systems. In the Delco system it consists of a set of weights, marked "governor weights" in the accompanying drawing. The weights are operated on an advance ring and so by changing the position of the sleeve with regard to the distributor shaft proper, in a manner very similar to the operation of a manual advance ring, they advance or retard the fibre timing cam according to the position of the automatic weights. The operation of these weights is also similar to that of the governors on a steam engine.

To time the ignition of the Delco system the adjustment screw is loosened, which allows the cam to move with respect to the shaft upon which it is mounted. Turning the cam in a clock-wise direction, or towards the right, advances the time of ignition, and counter-clock-wise retards it. Top dead center, of the compression stroke, or slightly before top dead center, is found in cylinder number one and the cam to which the rotor is attached is moved on the shaft until the rotor is making contact with the terminal in the distributor head marked number one. The timing adjustment screw is then screwed down firmly in place. The proper timing of the remaining cylinders is automatically taken care of by the positive design of the ignition system. It is most important that the timing adjustment screw be absolutely tight, otherwise the cam would soon slip out of place when the motor is running and so cause untimely ignition.

The common practice, upon discovering a defective spark plug, is simply to replace it. This in fact is the only way of procedure in case of spark plug trouble, but many things can be done to prevent spark plug deterioration.

The adjustment of the spark gap, or clearance between the two points of the spark plug is essential to correct ignition. This gap should be about .025 of an inch. Nearly all manufacturers of ignition systems furnish a gauge to properly set the spark and one of these should be in the possession of the mechanic.

The development of spark plug manufacture has been a long and tedious one, it being necessary for the spark plug manufacturer to keep pace with the rapid developments of the automobile motor. The Cadillac and Winton were the first to make a spark plug, but it was never satisfactory due to the fact that it had a tendency to absorb oil which soon rendered it useless as it destroyed the insulating properties of the porcelain, allowing the high tension current to leak through to the shell.

The best material for the manufacturer of spark plugs is universally conceded to be porcelain. The ingredients to enter into the manufacture of this porcelain are collected from all parts of the world. It consists of Kaolin, Flint, Feldspar and ball clay which are brought together and mixed in the proper proportions and then fired at the right heat in the same way that steel is given a heat treatment.

The best porcelain is the one which has the least amount of leakage of electrical current, but there is no porcelain made which has not a point at which it breaks down. It must be remembered that in a cylinder which is firing with too rich a mixture, a veritable furnace exists, and this soon has its effect on the porcelain of the plug. All the porcelains used in the manufacture of spark plugs are what are known as soft porcelains and these will absorb both carbon and water. When carbon is absorbed the porcelain is transformed in its internal structure and the leakage through the insulator increases. It therefore is the duty of the mechanic, in order to protect the spark plugs, to see that too rich a mixture is not used and to keep the carbon well cleaned

from the motor. Experiments have shown that a temperature of 1350 degrees Fahr. is reached within an internal combustion engine even when it is operating properly.

Spark plug terminals should be examined at frequent intervals to see that they are tight. The spark plug itself should be properly gasketed and firmly screwed down in the cylinder head to prevent any loss of compression. The terminals and plugs should also be kept clean and free from all grease and oil.

The size wire to use depends upon the amount of current that must flow through it and the length of the wire. The longer the wire the greater the resistance offered to the flow of current. Therefore, there will be too much drop in the voltage at the wire terminal if it is not of sufficient size. The conductor must be large enough to carry the required amount of voltage to a given point with less than 4 per cent. drop.

Nearly all automobiles are using a single wire system and the length of the wire is seldom more than ten or twelve feet. Primary wire is used for low tension, or voltage, as ignition, from the battery to the coil and from the coil to the timer, or for lights. It is usually flexible, consisting of several strands of wire. When used for lighting it can be "duplex" or even consist of four wires together and is usually encased in metal armor for protection. Secondary cable is used for high tension ignition currents. The wire is small but heavily insulated. Starting motor wire is very heavy, being several times the size of the secondary cable, but not so heavily insulated. Wire of this kind is used because it does not carry a high voltage, only 6 to 24 volts, whereas the secondary cable carries a voltage high enough to jump a gap.

The starting motor wire carries a large amperage or quantity of current. For instance the wire running from the storage battery to the starting motor, when first starting, must carry from 80 to sometimes 400 amperes, according to the size of the motor. This is only for a few seconds, but large wires must necessarily be used to carry this great quantity, even for such a short time. The wires running from the generator to the storage battery are much smaller, as the quantity of current which passes through them is only 5 to 25 amperes.

As a comparison, imagine water pipes. If it were desired to pass 150 gallons of water through a pipe in one hour it would require a much larger pipe than it would if but 25 gallons were to flow through in the same length of time.

The connection in electrical wiring should be soldered. The unsoldered connections may work as well as soldered connections at the time of being made, but the resistance always increases. In placing a wire terminal under a terminal nut, as on a spark plug, twist the wire in the direction that the nut turns. When connecting a wire under a nut a copper or brass washer should be used.

Wiring troubles are numerous if the wiring is not properly done. Oil and grease destroy the insulation, so the wires should be kept as free from this as possible. Moving parts of the motor or car must not touch the wires. Protect the wires from chafing. Avoid frayed ends. Tape all connections made in the wire. Connections must be tight as well as all terminals. These should be inspected, for vibration often jars them loose. A common trouble is one where connections of wire terminals to the storage battery and ground connections to the frame are not properly made. Cable should be used where the wire must make a sharp turn, as vibration from the motor is apt to cause a break in the solid wire.

A dynamo consists of two main parts, (1) the means of producing the strong magnetic field known as the field magnets and (2) a series of conductors in which the currents are generated by induction, called the armature. One of

the parts must be capable of rotation relative to the other. A current so produced is called an alternating current and the machine producing it is called an alternating current generator or "magneto," which has been explained in detail in a preceding lecture.

A direct current machine is fitted with a short cylinder called a commutator, made of a number of metallic segments insulated from each other, to which equidistant conductors of the armature are joined. The two brushes are placed so as to rub on opposite segments (for a two pole machine) of this arrangement so that the armature of the machine can be rotated while the brushes remain fixed and make contact with the segments as they rotate. The brushes are arranged so that just as the current is reversed in the conductor the segment attached to that conductor is under the brush. The current will be continuous in one direction. This is the type of machine found on all automobile lighting and ignition systems in use at the present time.

The principal parts of a generator are (1) the armature, in which current is generated (2) the field cores or magnets, either permanent, which is the horseshoe magnet as used in the magneto, or electro-magnet, which is only a magnet when a current of electricity is passing through it, (3) the pole pieces (4) commutator (5) brushes, either metallic or carbon and (6) regulation of current output.

Due to the fact that the current generated by a dynamo increases with the speed of the revolving armature, it is necessary to make some provision by which the flow of current can be regulated. This is known as regulating the charging rate and unless the charging rate be properly regulated there is danger of overcharging the battery. Over-charging the storage battery is indicated by the rapid evaporation of the water and the unnatural heating of battery.

There are two types of current regulators (1) the third brush type, as used by the Delco and (2) the vibrating type of regulator, as used by the Westinghouse. There are two arrangements of the Delco third brush, one under the commutator and one over the commutator. In the first the third brush is supported on an arm which is arranged to lengthen or shorten by means of a screw and slot in the arm. The moving of this brush in the direction of rotation increases the charging rate and moving the brush in the opposite direction, of course, decreases the charging rate. The generators leave the factory adjusted to give an ample charging rate at maximum generator speeds.

If the car is driven a great deal and the lights and starter used comparatively little it is possible to overcharge the storage battery unless the charging rate is decreased. If it becomes necessary to regulate the charging rate, the third brush will, of course, have to be moved. At any time that the brush is moved it is absolutely essential that a piece of fine sand paper, with the sand side next to the brush, be drawn between the brush and the commutator. If this is not done the brush will not make good contact and the charging rate will not be so high as when the brush is well seated. When the charging rate is increased or decreased it is always essential that it be carefully checked up by use of the ammeter on the combination switch which is usually located on the dash. In no case should the ammeter show more than 20 amperes. Checking of the charging rate should be made after the brush is correctly seated and the engine is gradually speeded up. The test should be made with all the lights turned off.

It will be found that the third brush that is mounted over the commutator is held in a brush arm that is made in two pieces. The part to which the brush is fastened has a slot through which passes two screws, attaching it to the other

part. By loosening these screws it is possible to slide one part upon the other and so increase or decrease the length of the arm. When the arm is shortened the charging rate is decreased and when it is lengthened the charging rate is increased.

The vibrating type of regulator as used on the Westinghouse generator is a mechanical regulator, being operated by the cam. Two silver contact points are made to vibrate by this cam and by their opening and closing alternately cut in and out a resistance unit. The greater the speed of the generator, the more rapid is the vibration of the two points and the more often is the resistance unit cut into the circuit, thus maintaining constant the output of the current or sustaining a given charging rate. This vibrating device is held in contact with the cam by spring tension and the increasing or decreasing of this spring tension regulates the charging rate.

To adjust the regulator a few rules should be strictly followed. Be sure that the fibre rests evenly on the cam and does not change its position when the pressure caused by the armature spring is removed. Be sure that the contacts line up properly and come together only at one point. Never file off the copper rivet on the regulator armature as it is used as a stop and should set .015 to .019 inches high. Set the high part of the cam under the fibre and screw the regulator core down until there is from .002 to .003 inches between the copper stop and the regulator core (use feeler gauge) and lock the core by means of the lock nut on top of the regulator. Set the proper voltage by the spring-tension-stop at the end of the armature spring to meet the test specifications of that particular machine. It is always well to wipe all oil and grease from the regulator parts before assembling and place a thin coating of clean vaseline on the sides and bottom of the fibre. When replacing regulator coils the correct style of core must be used, as some other style may make it impossible to set the regulator.

Aside from the regulating of the charging rate there are a few things that the mechanic should know about the general care of a generator. Through the proper care of this unit expensive repair work can many times be prevented.

Brush Care.—Once or twice a season the first coiled springs holding the brushes against the commutator should be raised and the brushes examined to see that they operate freely in their holders. Oil or dirt should be removed with a stiff bristle brush and gasoline. Faults in the brushes can be classified into five divisions—namely (1) grounded (2) poor spring tension (3) sticking in holder (4) poor fit to commutator surface and (5) over-heating holders. When grounded, it is due to defective insulation or dust deposit. When the spring tension fails, the brushes are worn too short, which would necessitate replacement, the spring tension is not properly adjusted or has been thrown out due to heat, or the springs themselves may be broken. However, the brushes should never be allowed to wear down too short. When the brushes stick it may be due to binding or from dirt and grease. When the brushes do not fit the brush holders it is a matter of manufacture. Overheating of the brush holders is caused by sparking due to ill fitting brushes or poor brush lead connections. If there is any sparking, or if the commutator becomes dull, it is sure to be the result of brush holder springs being too loose or due to excessive vibration caused by a bent shaft, an unbalanced gear pinion, or defective mounting. Always keep the brush spring away from the brush holder.

Carbon dust (providing that carbon brushes are used) may be worn from the brushes by the commutator and deposited in the lower part of the generator. This should be blown out with air as an excessive deposit may cause a ground.

Commutator troubles can be divided into two heads: (1) those due to defective manufacture and (2) those due to surface wear or deterioration in service. Defective commutators are generally denoted by sparking at the brushes and may be grounded, have a short circuit between their segments or have loose segments. Those that have deteriorated in service show a rough or blackened surface due to the following causes:—sparking from worn or short brushes, sparking on account of high mica, cheap brushes, oil collecting on commutator surface, loose copper segments, poor contact between brushes and commutator or poor contact due to weak brush spring pressure. Commutators should be kept smooth. If blackened or rough they can be dressed with fine sand paper, while the armature is rotating.

Sometimes a decided "squeak" will come in the generator, which is caused by glazed brushes. In order to eliminate this, the glazed surfaces must be rubbed down. Place a strip of sand paper between the brushes and the commutator with the sanded side of the paper against the brushes, turning the armature until the brushes are smooth and the glazed surface has been removed. Never use emery cloth.

Between the commutator segments mica should not protrude. This can be dressed down on the lathe or in some instances filed down with a very fine cut file, but care must be taken that no small particles of copper are left bridging across the segments. This work must be done with armature removed and preferably on a lathe. If the commutator is greasy wipe clean with a clean cloth but never use waste.

The principle of the transmission is to allow the engine to speed up until the energy which is stored up in the fly wheel is sufficient to keep the shaft revolving at a speed showing no great percentage of variation. A second and principal duty, is to adapt the engine to a heavy load, which under the circumstances would cause it to slow down and stall, if required to work under such conditions any length of time.

For example—it may be assumed that a man is raising a bucket of water from a well by winding a rope around the drum of a windlass. The bucket must be raised a certain number of feet every minute. Then if the bucket of water weigh such an amount as to require all of his strength to fulfill these conditions, and that any extra weight added to the bucket would overtax his strength to such an extent as to make further progress impossible, it is evident that some mechanical contrivance is necessary which will enable him to exert the same strength, but apply it through a longer period of time. To make this plain it may be assumed that he wished to lift a barrel weighing six hundred pounds ten feet. It is evident that this could not be done in a direct manner. If, however, he should build an incline long enough he would be able to roll it up accomplishing the same work but taking a longer time. Another way would be to use a lever.

Now, returning to the first illustration, instead of turning the drum of the windlass direct by hand a gear may be placed on the end of the drum and constructed to mesh with a smaller gear attached to the lever. To illustrate the principles involved it may be assumed that the large gear on the drum is three times the diameter of the small gear. It will therefore require three revolutions of the small gear to one of the large gear, and the pressure exerted will be only one-third of that required if the crank were fastened to the drum direct. To compare this with the conditions of automobile operation, the work required to lift the bucket may be represented by the work required to drive the machine, and the man's effort or force applied to the lever of the windlass by the pressure exerted on the piston of the engine. Transmissions may be divided into

three classes: the friction drive, the planetary and the sliding gear transmissions.

The "Friction-Drive" type is practically obsolete, and consisted of a large disc, turned by the engine, and a large wheel at right angles to the disc, the wheel turning a "Jack Shaft" from which the rear wheels were driven by sprockets and chains. The wheel could be moved side ways on the "Jack Shaft" by a lever and pressed against the disc, or released from it by a foot pedal. When the wheel was moved near the center of the disc, and pressed against it, it turned slowly. When it was moved near the outer edge of the disc, it turned faster. The chief trouble with this type was "slipping," wearing out of the leather facing of the wheel and wearing out of the bearing which supported the disc-shaft, due to the fact that, when running, the wheel was forcibly held against the disc near the edge, and caused a side-thrust on the shaft.

The "Planetary" type is used almost exclusively on the Ford and has only two forward speeds and "reverse." The fly-wheel has three studs, each of which carries three gears of different sizes fastened together to form what is called a "triple-gear mesh" with three gears of different sizes in line with the engine-shaft. The inner one, next to the fly-wheel face, is fastened to the drive-shaft which delivers the power through to the rear axle. The other two central gears float on the drive shaft and are connected to the two drums nearest the engine. Surrounding these drums are brake-bands which can be tightened by foot pedals. If the slow speed (middle) drum is held, the second (middle) of the three central gears around the engine shaft will be held stationary. This makes the triple gears rotate on the studs as the fly-wheel revolves. In doing this, they drive the first central gear, which is located nearest the fly-wheel and fastened to the drive-shaft slowly forward due to the difference in the sizes of the gears. If the middle drum is gripped instead, but pushing on the reverse pedal, the larger of the three central gears (third from the fly-wheel—around the drive-shaft), is held. This makes the triple-gear revolve again on the studs as the fly-wheel revolves, but since this reverse gear is larger than the driver-gear, the motion of these triple gears will turn the driver shaft slowly backward. For high speed, the entire mechanism is gripped solidly together so that it revolves at engine speed. A multiple disc clutch is used to engage and disengage the direct drive. A third drum is used for the service brake.

This mechanism very seldom needs repair, with the exception of the replacement of the transmission bands, the linings of which wear out in a comparatively short time. To replace these, remove the transmission case cover, first loosening the adjustment of the bands so that the cover will slip off easily. The bands may then be removed one at a time by sliding them colse to the fly-wheel, and turning them around on the drum, so that the ends are at the bottom. The old bands may be re-lined, or as is customary, new bands with the lining already attached may be put on. If the old bands are to be re-lined, use plain brake-lining only. Never use a lining which has the fine copper wires in it, like "Raybestos," as the little pieces of wire are apt to cause short circuit in the magneto, which is enclosed in the same housing. After the new bands have been slipped on the drum they should all be turned so that the ends are in line at the top. In order that the adjusting screws and springs will come into proper position with the ends or lugs of the bands when the cover is put on, the ends of the bands must be squeezed together as far as possible, and clamped, or wired to hold them while the cover is replaced. A new felt gasket should be used under the cover in order to prevent oil leaks. After the cover is in position, the clamp of wire around the band ends is removed.

The adjustment of the clutch is very simple, and is accomplished by turning the adjusting screws on the clutch fingers.

Noisy action of low speed and reverse gears usually mean worn-out bushings on the fly-wheel pins around which the triple gears revolve, or the pins themselves may be loose. If repairs or replacements to these internal parts are necessary, the engine must be removed from the frame, the crank case removed, and the transmission disassembled. The bushings on the inside of the drums should be examined for wear, and new drums replaced if any appreciable "play" is noted.

The "sliding-gear" type of transmission, commonly called a "gear-set" is used on practically all trucks. The transmission case contains two shafts, a main shaft which is either square or "milled," so that gears may slide back and forth on the shaft, but must turn around with it, and a second, or counter-shaft, on which several different sized gears are keyed. By means of a lever, the gears on the main shaft may be meshed with those on the counter-shaft and the various speeds obtained.

The main shaft is not a continuation of the clutch-shaft, but turns independently inside the clutch-shaft in a bushing. The clutch-shaft turns the gear just inside the case, which is always in mesh with the gear on the counter-shaft. Therefore, the main shaft does not turn when the clutch-shaft and the counter-shaft are turning, unless one of the sliding gears on the main shaft is meshed with a gear on the counter-shaft. In the gear-set shown, first, second and third speeds would be obtained by sliding the gear on the right of the main shaft against the driving gear on the end of the clutch shaft. Both of these gears have "dogs" on their sides which engage when the gears are brought together. In this case, the counter-shaft is not used, and the position is called "direct drive." The principle is the same in a three-speed transmission, direct drive being third speed instead of fourth. "Reverse" is obtained by meshing one of the sliding gears with a small "idler" gear, which is turned by the counter-shaft. As the power is transmitted from the counter-shaft to the main shaft through an intermediate or "idler" gear, the main shaft will be reversed. When changing from one gear to another, the clutch is disengaged so that the gears are free from strain.

The sliding gears are moved by means of "shifting forks," moved by rods connected to the gear-shift lever. These forks slip into collars on the side of the gears. Careless drivers sometimes try to force gears into mesh with the result that these forks are bent and the gears cannot be meshed, or unmeshed. In this case, the transmission case cover must be removed, together with the shifting mechanism, and the fork straightened.

To prevent the gears from sliding about on the main shaft independently and to hold them in whatever position they may be placed, grooves are made in the shifting rods at the proper positions so that a pointed finger under spring tension snaps into the groove, and holds the gear firmly in position. Occasionally these fingers will stick on account of dirt, or a little roughness and will make shifting difficult. They can be easily removed and cleaned up by unscrewing the plugs over them.

The sides of the gear teeth are chisel-faced, to make engagement easy. However, by constant use, the set may become "burred" and a noisy engagement, or clashing of the gears will result. It is then necessary to remove the gear and grind the edges smooth on an emery wheel. Worn gears and worn bushings at the ends of the shaft are also sources of loud grinds, and noisy operation. Stripped gears are usually the result of careless driving, the gears being crashed into mesh while the clutch is partially, or entirely engaged. A clutch so adjusted that it does not drag, and a clutch-brake that is so arranged that the clutch-shaft stops revolving at once, will go far toward avoiding the clash-

ing of gears in shifting and the prevention of transmission trouble in general. If it is necessary to repair or replace gears or bushings, the transmission case must usually be removed from the car. The top is removed, to which are fastened the shifting rods, and forks. The two shafts can then usually be removed by taking off one or more plates at the front of the case. In some cases the whole end can be removed, although of course constructions vary.

As to lubrication of the transmission, always try to follow the instructions of the manufacturer. In general, a light "fibre" grease is best. Never use "cup-grease" in the transmission, or differential, as it breaks up, and loses its lubricating qualities. Any stiff, or butter-like grease will be thrown from the gears by centrifugal force, so the ideal lubricant should be molasses-like, and flow over the gears without being thrown. The oil drained from the engine is "waxy" and makes a good transmission lubricant after it has been strained and mixed with a little "fibre" (transmission) grease.

Motor Truck Company Drivers' Course

MAINTENANCE

LECTURE IV

The most common form of differential is designed to equalize the turning effort of both driving wheels even though they are turning at different speeds, as in rounding a corner. Figures 1 and 2 (see next page), represent an ordinary bevel gear type of differential. Power is applied through the driving pinion to the bevel driving gear, sometimes called a bevel ring. This is bolted or riveted to a flange on the differential casing. Mounted in the differential casings are two differential side gears each of which is attached to one of the axle shafts by a square or spline fit, or sometimes by key. A cross or set of studs is mounted between the two halves of this differential casing. Mounted on the arms of this cross or on the studs, and free to turn around, there are small bevel pinions which mesh with the two differential side gears. When one wheel runs faster than the other the pinion turns to give the necessary compensation in speed between the two differential side gears.

Another form of equalizing differential, known as a spur gear type, accomplishes the same purpose as the differential which employs bevel gears. It makes use of two spur gears for the axle shafts as pairs of spur pinions meshing together instead of bevel pinions.

The weakness of the ordinary form of differential lies in the fact that as one wheel only has traction, all that can be accomplished will be a spinning of that wheel. The wheel which has traction will receive no more pull than that required to spin the easier moving wheel. To eliminate this difficulty there have been designed differentials which are sometims classified as over-running or as the over-wheel type. The mechanism is so arranged that the power is applied always to the slower moving of the two wheels. On a turn this applies all the power to the inner wheel and allows the outer one to run free. If one wheel has poor traction both wheels will be driven at the same speed just as if they were mounted on a solid axle.

Some of the earlier designs of differentials were faulty because there was too much back-lash and lost motion in the mechanism which could be taken up with a sudden jerk.

Another form of differential employs worm instead of bevel gears for the equalizing mechanism within the differential case. It is intermediate in action between the equalizing and the over-running types and it has some of the advantages of both.

On a few makes of trucks a device known as "differential lock" has been provided so that the driver, by applying a convenient pedal lever could lock the differential and secure the same effect as would be obtained with a solid axle shaft.

The term dead axle applies to an axle which is stationary. The wheels are mounted on spindles and are driven by side chains, the differential being located on the forward shaft, known as a countershaft or jack shaft. Chain drive for motor trucks is losing popularity the same as it did several years ago on passenger-carrying cars.

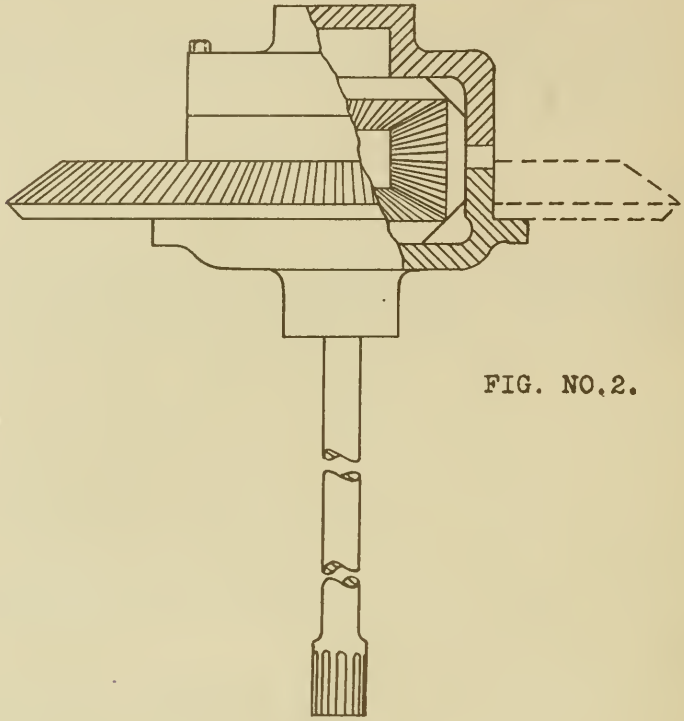


FIG. NO.2.

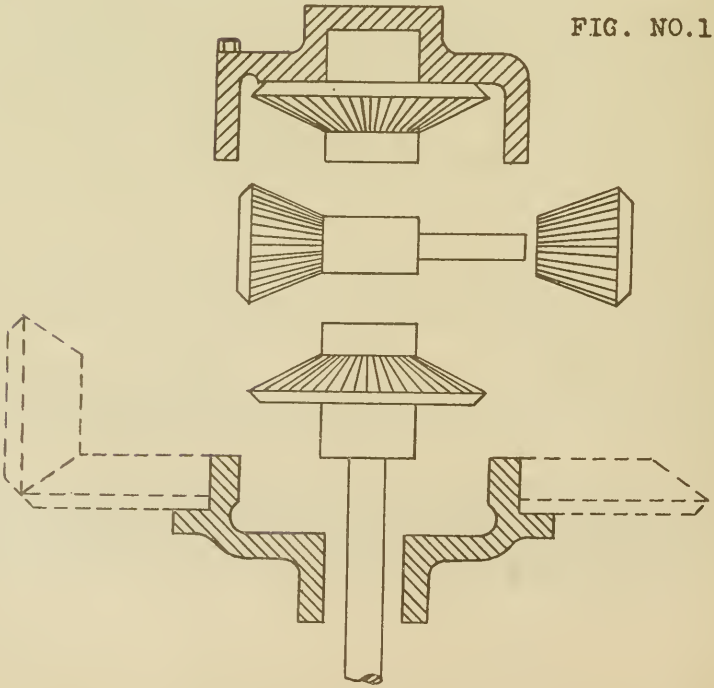


FIG. NO.1.

Sketch in section illustrating differential.

The term live axle is often used to cover all types of axles which contain revolving drive shafts. The axles used in most of the heavier trucks purchased by the Government are of the type known as full floating. The hubs of the rear wheels are provided with two bearings each and are mounted on the outside of a tubular rear axle housing. The inner ends of the axle shafts fit into the side gears of the differential. The outer ends are provided with flanges either integral or securely attached, which are bolted to the wheel hub (or in some cases are notched and held in place against the notched head of the hub cap). When the power is applied to the differential by means of the bevel or worm gears, the axle shafts are carrying the turning effort necessary to drive the rear wheels. The axle shafts support the dead weight and are subjected to no binding strain, their only duty being to drive the wheels. The axle housing serves to support the weight and carry any binding and straining.

The design of the full floating axle is generally such that the axle shafts and the differential may be removed and the truck may be left standing supported by its own wheels.

The term semi-floating applies to the type of axle where the rear wheels are keyed to the tapered ends of the axle and the axle shafts are depended upon to carry the weight and also any bending strain which may come upon them when the truck rounds a corner. The outer bearings are then located between the axle shaft and the housing. This generally makes it necessary to pull the wheel off the tapered end of the shaft before this bearing can be removed and the axle shaft withdrawn. It is, therefore, necessary to remove both the wheels and the axle shaft before the differential unit can be taken off for inspection, cleaning, adjustment or repair.

The term three-quarter floating applies to the axles which are so constructed that only one bearing is mounted in the hub of each wheel between the hub and the housing and the axle depended upon to maintain the alignment of the wheels, that is, keep them from wobbling. The fact that this puts some bending strain on the axle shaft distinguishes it from the full floating type.

Another type of axle, known as the internal drive type, has become very popular in the last few years, especially for light trucks. This form of axle employs rigid forging like that of a dead axle, on the ends of which the wheels are mounted, to support the weight of the truck. The differential is bolted to the axle near the center. From the differential run two driver shafts on the outer ends of which are mounted spur pinions which mesh with internal gears about the size of ordinary brake drums mounted on the hubs of the rear wheels.

When the power is to be applied to all four wheels of the truck instead of only two, special axle construction becomes necessary. One method is to apply the power to the wheels by the use of internal gear drive. The differential housing is mounted above the solid axle forging. The axle shafts are provided with universal joints located directly above the steering knuckles so that the wheels can be steered.

Another construction employs a hollow rear axle in which are housed the differential and the two axle shafts. The steering knuckles and the ends of the axle housing are made larger than usual, and in them are housed the universal joints. The short shaft which extends from each universal joint outward through the hollow spindle, is provided with a flange which serves to drive the wheel. The mounting of the wheel on the outside of the hollow spindle with the drive through this flange is quite similar to that employed in full floating construction.

If the front wheels only are steered, there should be one differential to divide the turning effort equally between the front axle and the rear, and yet allow the front wheels to run at slightly lower speed than the rear wheels, since they travel a shorter distance as when rounding a corner. Each axle would, of course, require a differential to permit the application of power to both wheels and prevent slipping when rounding a corner.

If all four wheels are controlled by the steering gear only the differential in the front and rear axles is required as the front and rear wheels track when turning.

From time to time the rear axle should be jacked up and the fit of the rear wheel bearing determined by making an effort to wiggle the rim of the wheel. While one man attempts to move the wheel, another can place his hand on a brake support bracket and the edge of the brake drum, and so easily determine the amount of play.

Spring clips, pins in radius rods and truss rods, and also the brake rods should be inspected carefully, at least once a week.

The worm shaft should be examined for the amount of end play. No adjustment should be attempted by anyone except a skilled mechanic. If the driving worm is mounted between two tapered roller bearings the desired play may be 1/64th of an inch to allow for expansion as the worm becomes warm. If a ball thrust bearing, located at one end of the worm is employed, the amount of end play may be so little that it cannot be felt.

Lubrication is probably the most important detail in connection with care of the rear axle.

To insure effective lubrication of the driving gears the differential mechanism and rear axle housing should be kept filled to such a depth that the driving gear will dip an inch or an inch and one-half in heavy mineral oil, about the consistency of molasses (similar to 600-W). This will follow the gears as compared with hard grease in which they might cut tracks. Particles of metal worn or chipped from the corners of the gear teeth will sink to the bottom of this heavy oil whereas with grease they might be carried in suspension into the gear teeth and bearings where they would cause noise, wear or even breakage.

The rear axle housing should never be filled with a lubricant to a greater depth than that recommended by the manufacturer in his instruction book (sometimes indicated by high level drain plug).

The manufacturer generally does not recommend the use of graphite with the oil in a worm driven rear axle.

The drive pinion and internal gear of the internal drive rear axle are in most cases lubricated with grease or graphite grease.

The grease cups and oil cups on various points of the rear axle assembly such as on the brake shafts, spring saddles, torsion and radius rods, etc., should be filled faithfully.

When chain drive is employed the chain should be removed every two or three weeks and washed in kerosene to remove the grease, dirt and grit. It should then be soaked in a hot mixture of tallow and graphite and then drained and wiped off very carefully. In this way the lubricant gets inside of the rollers where it is needed, and to a certain extent the grit is kept out.

The differential case should be drained, flushed with kerosene and refilled every 1000 or 2000 miles, as recommended by the manufacturer.

As we have just enumerated the several different types of rear construction, it may be well to mention a few of the relatively important repairs. Besides having a proper adjustment of the driving pinion, it is very essential that the entire moving mechanism is free to turn from either shaft or axle. Generally the parts of a differential suffer little or no wear, but should they occasion replacement, this is accomplished by removing the housing proper, and dismantling the pinion casing, replacing and assembling. Adjustment in rear axles is more or less a matter of shop practice and will be treated in detail in the next period.

In order that the power plant of a motor truck may be started and kept running, but still permit the car to remain stationary, it is quite important that some mechanism be provided for this purpose. Likewise if we desire to maintain a certain engine speed but require a greater speed of the vehicle, means also must be provided to permit the changing of gears. For example: Assuming that we are in first speed and the truck is moving five miles per hour and the engine R. P. M. is 900, and we desire to go to second. The difference of speed of gears would not permit them to mesh. This mechanism which allows for the above mentioned requirements is called the clutch. As a result of experience the friction clutch is universal.

These devices are capable of transmitting any amount of power if properly proportioned and permit a gradual engagement and a positive disconnection. Most friction clutches are simple in form, easily understood and may be kept in repair and adjustment without difficulty.

The main object in designing a clutch is to increase the amount of friction existing between the parts to as great a degree as possible. The transmitting efficiency of the clutch will vary with the coefficient of friction between the surfaces, and the more friction between them the more suitable the clutch will be for transmitting power. A metal usually forms one frictional surface in all forms of clutches, and some types have been designed and used successfully in which all frictional surfaces are metal.

The materials used generally for the metallic plates are cast iron, aluminum and bronze castings and sheet steel and bronze, usually in the form of thin stamped discs. The non-metallic frictional materials generally used are leather, asbestos fabrics, textile beltings and cork. Leather is the best lining or facing for clutches where the frictional area is large. When used it must be kept properly lubricated and soft, if it becomes dry it will engage very suddenly and the clutch action will be harsh. On the other hand too much lubricant must not be applied or the clutch will slip. Oak tanned leather is generally used because of its good wearing qualities. It is a very resilient material and possesses a satisfactory degree of frictional adhesion when pressed against a cast-iron member. Asbestos fabrics are being applied in many forms of dry plate clutches and have been used to some extent in facing the male members of some clutches. These are not as elastic as leather. When cork is used it is inserted in the metal surface in suitable holes which are machined to receive the inserts. Cork possesses peculiar qualities which make it suitable for use in a clutch. It has perhaps the highest coefficient of friction of any of the materials employed and is not materially affected by either excessive lubrication or the lack of it, and possesses desirable wearing qualities. In application cork must be used in inserts, because it is too brittle to be used in sheet form with any degree of success.

The proper use of the clutch is of importance from the mechanical standpoint, as improper use will necessitate repair and re-adjustment. The clutch should always be either engaged or disengaged. Do not drive with the foot

on the clutch pedal. The weight of the foot on the pedal and a little nervous tension of the driver's leg is sometimes just sufficient to hold the clutch out far enough to "slip it" on a hard or sudden pull. Another way to spoil a clutch is to throw it out in traffic until the car comes almost to a standstill—then to speed up the engine and slip the clutch in with the gear lever still in high speed. When the car slows down with the clutch out, the gear lever should be shifted to second speed and if the car comes to a complete stop should be shifted to low speed. Another important point in the proper use of a clutch is to engage the clutch gradually and not to bring it in with the engine racing. It is always better to run on the engine as much as possible, throttling it down, instead of constantly throwing out the clutch.

One of the simplest forms of clutch is the cone clutch. This consists of a metallic cone covered with leather or other frictional material; a clutch spring which holds the tension of the cone to the flywheel; pressure or plunger studs which are spring mounted and placed under the clutch leather at various points and allow gradual engagement of the frictional surface, clutch rollers on the shifter yoke, ball thrust bearings on the clutch shaft which prevent spinning of the clutch.

Cone clutch troubles can be divided into two distinct divisions: fierce engagements, grabbing, slipping or spinning.

There are several causes for the clutch grabbing. A dry or hard clutch facing will produce this and can be remedied by an application of neatsfoot oil. The leather should first be cleaned with kerosene. Projecting clutch rivets also cause grabbing. This is indicated by a grating or grinding sound in the clutch and can be remedied by placing a center punch against the rivet head and hammering until the head is below the surface of the leather. Clutch lever *linkages* out of adjustment will also cause this trouble. The amount of movement between the surfaces of the clutch is small and it is important that no looseness exist in the pedal connection. There should not be excessive tension on the clutch spring as this will cause weakening of the spring and also bring an undue strain on the ball thrust bearings. If pressure or plunger studs are employed under the clutch facing care should be taken that they are properly adjusted. The clutch rollers on the shifter yoke may be worn, due to lack of lubrication. If they run dry they are liable to seize and prevent the clutch from releasing entirely. In this case new rollers must be fitted.

There are also quite a few conditions that contribute to clutch slipping. A burned or worn clutch lining will cause this and usually results from allowing the clutch to slip when starting or changing speeds or from using the clutch too much instead of throttling the motor down. Even though worn to a certain extent the application of neatsfoot oil will improve its operation. If the neatsfoot oil does not produce the desired result a new clutch facing must be installed. A cone clutch will also slip, due to the clutch leather being oily and greasy. The cure is to wash the oil off by spraying kerosene and then dress the leather afterwards with neatsfoot oil. The oil can also be absorbed by using powdered Fuller's earth, which is sprinkled over the surface and allowed to stand for several hours. Do not use dirt or sand to prevent a slipping clutch as this will cut the leather. If the leather is worn down and it cannot be raised enough by adjusting the plungers to make it firmly grip the metal it is usually necessary to replace the facing. However, it will sometimes be found that the clutch is not fully engaging and at the point of its engagement in the flywheel, a ring has been worn in the leather. This ring can be dressed down with a rasp which will usually allow the clutch to engage

deeper in the flywheel and a good clutch can be obtained without replacing the facing. Weak clutch spring tension will also cause the clutch to slip. In this case the adjustment must be tightened. If there is no adjustment provided, the tension can be increased by placing a washer between the spring and its seat. Slipping is also caused by the clutch shaft being out of line. This is many times due to too great a spring tension causing the balls to break in the thrust bearing and cutting the ball race, lowering the clutch shaft out of line. It also may be due to a bent clutch shaft or lack of alignment.

Clutch spinning is often due to excessive friction in the spring thrust bearing, though sometimes faulty alignment of the flywheel and clutch cone will prevent the engaging surfaces from entirely clearing each other. A bent clutch shaft might also be the cause of this. Sometimes the fault lies in the clutch, a heavy rim or cone will store up energy and continue to revolve when disengaged. When a clutch spins from a lack of alignment or adjustment the remedy is obvious, but if the fault is in the design, a clutch brake should either be fitted or the clutch rim lightened by drilling or machining away the metal at or near the outer circumference.

It is necessary to lubricate the moving parts of a clutch, the rollers or clutch yoke and the ball thrust bearings, but it is essential to its operation that lubricating oil be kept from the clutch facing as much as possible, as this type of cone clutch is supposed to run dry, except for the application of the necessary neatsfoot oil to keep it flexible.

Sometimes a clutch will fail to release and this is known as a "frozen clutch" and is usually due to a rusty or tight pedal connection or loose pedal link connection. Clutch yoke rollers run dry sometimes from too tight a spring adjustment.

Excessive wear makes it necessary sometimes to replace the clutch facing. Usually the manufacturer can furnish suitable clutch facings or leathers, which are fastened at the ends and cut to the proper size. After the old facing has been removed the new one can be forced upon the clutch web. The easiest way to accomplish this is to first soak the leather over night in water, which will make it possible to stretch it into position. When the leather shrinks it will fit very closely and can be riveted in place without any difficulty. The rivets should be countersunk at least 1/16" below the surface of the leather. Be sure, before replacing a clutch leather, that the cone itself is true. If the cone is out of true it should be turned true in a lathe. However, if it is only out of true .002" or .003", it may be turned true after the clutch leather has been installed, cutting away enough of the leather to make up for this defect. Before attempting to replace the clutch facing be sure that the replacement is absolutely necessary. Many times, by repairing the old facing a better clutch will be obtained than if a new one is installed.

The disc clutch, or multiple disc clutch, consists of a number of discs which are pressed together when the clutch is in, the friction between them causing one to drive the other. This type of clutch is very compact. To illustrate the principle of the disc clutch, place a silver dollar between two silver half-dollars and squeeze them together between the forefinger and thumb of one hand. With the other hand try to revolve the dollar not moving the halves. It requires only a slight squeeze to produce sufficient friction to make it impossible to move the dollar.

The lubricated multiple disc clutch is generally so constructed that steel and bronze plates alternate and are held in contact with a strong spring. This type of clutch sometimes slips due to the oil in which it operates becoming too thick or gummy. The process of eliminating this is to, first, drain the oil

out of the clutch; second, wash well with kerosene, placing the kerosene in the clutch and while the motor is running engage and disengage the discs by pressing on the foot pedal. Then remove the kerosene and fill the clutch to the specified level with clean oil. Some manufacturers recommend that cylinder oil and kerosene in equal portions be used to make the oil bath in which these clutches run. The spring tension must be properly adjusted as this is many times the cause of the clutch slipping. However, the tension must not be too great as this will cause the clutch to grab.

The dry type of multiple disc clutch in construction is very much the same as the lubricated type except that one set of the discs is faced with some sort of friction material, such as Raybestos, these plates alternating with the metal ones, which are usually of steel.

The slipping of this type of clutch is often caused by the lack of proper clearance between the clutch opening fingers and the release plate.

The clearance should never be less than $\frac{1}{16}$" or more than $\frac{1}{8}$" when the clutch is in. This necessitates the adjustment of the clutch opening fingers. Another cause for slipping is too little tension on the clutch spring. Never tighten the clutch spring nuts until the release fingers have been adjusted to the proper clearance. Neither of the above mentioned adjustments would have any effect if the lining on the discs is worn so thin that the clutch casing seats on the flywheel. When worn thus the clutch must be removed. An excess of oil on the clutch facing would also cause the clutch to slip and should be carefully cleaned. This can be accomplished by washing with kerosene or gasoline. Continual slipping causes the discs to get very hot, warping the steel discs and raising the rivets on the lined discs so that they cause the clutch to chatter, with the possibility of grooving the discs and giving them a permanent warp. A noisy clutch, particularly when released, is usually due to a worn clutch thrust bearing and replacement of the bearing is necessary.

To remove the clutch it is necessary to remove the bolts on the clutch cross shaft and spring it up. Then remove the clutch cross shaft and the nuts that hold the clutch spring bolts. These bolts must also be removed. Then pull the clutch out and remove from the frame. Place the ring assembly on the bench with the clutch rings up and remove the snap ring. Then remove all of the friction plates, noting how the rings are removed so that they may be again built up in the proper sequence. Clean all parts with gasoline and scrape out the clutch ring recesses both on the flywheel and the clutch hub. If the asbestos faces on the discs are worn they must be replaced. The split rivets holding them should be opened down below the surface, if the facing does not have to be removed. To replace the facing, cut off the head of the old rivets, taking care that the discs are not sprung out of shape in so doing. Examine each disc to see that it is not sprung or warped out of shape and note whether the steel discs are grooved. If either is the case the discs must be replaced. Using each disc as a template, drill the rivet holes in the new facings, countersinking slightly for the rivet heads. The new facings can best be obtained from the car maker and this should be done if possible. Using solid copper rivets, rivet the new facing to the disc. Examine ball and roller bearings of the clutch for wear and the clutch bushings for looseness. Replace with new ones if any amount of wear is evident. In assembling the clutch make certain that the rings are inserted in the proper relation to each other. In assembling the clutch it is necessary to use some sort of clutch spring compressor. Different types of compressors are suggested by various manufacturers, or an arbor press, or even a vise can be used to advantage.

If the clutch starts to slip, adjust it at once. Do not allow a clutch to be used in a slipping condition. Use no oil in the interior of this type of clutch, except on the bearings and these should be carefully oiled, making sure that none of it has an opportunity to work into the discs. Do not drive with the foot on a clutch pedal.

The plate clutch is one where one plate is clamped between two others. The single plate clutch is a popular type of clutch. It is a variation of the disc type, the latter comprising a large number of narrow discs, while the former usually consists of but three broad discs or plates, the ordinary type having two driving plates and one driven plate. This clutch, like the multiple disc type, is of both the lubricated type and the dry. The adjustments of these types vary in all different makes and are specified by the manufacturers. The causes for trouble and their remedies are practically the same as in the multiple disc type.

A universal joint is a flexible connection between two shafts which permits one to drive the other, although they are not in line. Universal joints are usually placed in front and rear of the driving shaft. They are necessary on automobiles with shaft drives, for while one end of the driving shaft is attached to the transmission shaft, which is on the frame, the other end is connected to the axle, and is constantly moving up and down as the wheels follow the uneven contour of the road. In other words, the driving unit, or engine, is in one plane and the drive unit, or axle is in another, and the universal joints make possible the transmitting of power from one plane to another. if no universal joints were used, the shaft would jam in its bearings from the up and down motion.

Various types of universal joints have been devised to take the place of the modified Hookes coupling which is so widely used in transmitting motion from the power generating engine to the rear construction of the modern automobile. The "spring plate" and the "leather disc" have both been used with some degree of success, but the majority of manufacturers have adhered to the first mentioned type, which has been most successfully developed by the Spicer Manufacturing Co. and is known as the Spicer Universal Joint.

The universal joint is an important element in practically all shaft drive cars, some constructions using but one joint, if the propeller shaft is protected by a long housing. Other systems employ two universal joints, one at each end of the exposed propeller shaft. Universal joints on many early cars were run exposed and considerable trouble was experienced due to the rapid wear of the bearing parts. When exposed there was also considerable difficulty in keeping the joints properly lubricated. The modern forms are housed inside of a casing member, which is not only designed to exclude dirt and grit from the bearing surfaces, but which is also depended upon to retain the lubricant.

Because of the adoption by many manufacturers of universal joints which correspond closely with the Spicer Universal Joint, that type of joint will be used as an example in discussing the care and repair of same.

Every 1000 miles the grease hole plugs should be removed and the joint properly greased. The kind of grease recommended by different car manufacturers varies, but the oil known as "timing gear oil" having a consistency between heavy cylinder oil and vaseline, may be used in most cases. Graphite grease also makes a good lubricant. Do not use too much grease or it will have a tendency to work out, the centrifugal forces of the revolving joint throwing it all over the surrounding portion of the car. The joint should be filled about $\frac{2}{3}$ full.

The forward universal joint, when two joints are used, is provided with a dust cap and felt washer on the rear end of the sleeve into which the end of the propeller shaft slides. This cap should be turned to the right occasionally in order to keep the felt washer tight and prevent the leakage of grease. Both joints have flax packing between the two parts of the pressed steel casings. The packing can be tightened by loosening the binding screw and turning the casing, adjusting nut or ring in the right hand direction. If grease works through the packing in the front universal joint, the joint will not only suffer from lack of lubrication but the grease is apt to be thrown into the brakes, rendering them inoperative.

When the universal joint has been disassembled and is being assembled again, care should be taken to see that the holes in the flange and the inside casing are matched up in such a way as to bring the oil hole, which is closed by a threaded plug, opposite an open space in the joint, and not opposite one of the lugs, which would prevent the introduction of grease through the hole. The purpose of the grease hole is to allow examination of the lubricant within, and the injection of oil or grease at any time by the use of an ordinary grease gun.

Sometimes these joints are encased in a leather boot and in cleaning the joint it is necessary to remove this. This joint should then be washed with gasoline or kerosene. In some cars the housing enclosed by the leather boot is a small cylindrical sleeve held by four set screws. When these are removed, the sleeve may be slipped off of the universal joint, leaving this free to be cleaned. The used oil should be removed entirely and new grease put in.

Should a knock or rattle occur in the joint, it is a case that necessitates disassembling and rebushing of the working parts. If the wear is so extensive as to cause an excessive "back lash" when either applying the power or the brakes, it is advisable to replace the worn joint with new ones.

Springs

The springs used on a motor truck are generally of the semi-elliptic type. The leaves are held together by a center bolt and are secured to the axle by spring clips. Since the length of the springs from end to end increases under the load, either end or both ends of a spring must be fitted with shackles or with sliding surfaces.

The springs are intended to maintain the proper location of the axles. On some makes of trucks radius rods are provided at the rear to keep the rear axle in its proper position. On almost all trucks the front springs are provided with shackles at the rear end and are pinned to the truck frame at the front end and are depended upon to maintain the proper location of the front axle.

The end of the springs where the bolts or shackles and pins pass through the eyes should be lubricated daily. Grease cups, oil cups or oil reservoirs are generally provided. If they are neglected it will be a matter of only a short time until the bolts or shackle pins will become worn very badly and the drilled oil holes or grooves which are provided will become obstructed.

When deflection of the springs takes place, the leaves slide a small amount, one against the other, just as the individual cards do when a pack is bent. If the leaves are not lubricated, water works in between them and causes rusting and pitting. When they have become badly roughened they offer very much more resistance to deflection and more of the shock of the road either must be taken up by the tires or is transferred to the frame and mechanism of the truck.

Lubrication of the leaves can be accomplished easily if the rebound clips are loosened and the frame is jacked up to relieve the springs of the weight. The leaves can then be pried apart and a paste of graphite and oil be spread between them with a knife. It is possible to get oil such as that which has been removed from the engine base to run in between the leaves by applying it along their edges.

The lubricant between the spring leaves will be absorbed in a very short time if the truck is operated during wet weather and mud is allowed to dry on the springs. In dry weather the lubricant will last for several months.

The leaves of a spring are made of a special grade of spring steel, generally some alloy steel and are carefully heat treated to make them tougher and to give them greater endurance. Since they are weakened by the hole drilled for the center bolt, that is the place where the breakage seems most liable to occur. If the spring clips which fasten the spring to the axle are kept at all times as tight as possible the bending of the leaves at the center will be almost prevented and there will be no danger of their breaking at that point. No matter how tightly the nuts on the end of the spring clips are drawn, it will be necessary to take them up a small amount from time to time. They should be tried at least once a week.

In the event of spring breakage, a wooden block or a wooden block and rubber bumper is placed between the spring and frame or between the axle and frame in order to raise the frame to the proper height. The truck should then be driven carefully until the spring has been replaced.

Brakes

The brakes used on a motor truck are generally of one or the other of two types, internal expanding or external contracting. The brake shoes or brake bands are generally faced or lined with a material woven like canvas belting or like lamp wicking, but consisting chiefly of asbestos, sometimes reinforced with fine brass wires. On account of its heat resisting properties this has proven to be the most suitable material for brake linings. On a great many European and a few American trucks and cars, a cast iron brake shoe is employed to work against the steel drum without any lining or facing.

Brakes are sometimes classified according to the method of operation, as hand or foot brakes, also as service and emergency brakes.

The brakes may be located either in the hubs of the wheels or on the propeller or jack shaft. The location on the propeller shaft makes it possible for the driver to place considerable strain on the universal joints, driving shaft, driving gears, differential and axle shafts. When such a brake is used the parts are generally designed with greater strength to withstand this strain. It is however, desirable to use the brakes operating on the rear hubs in preference to the transmission brakes under emergency conditions.

When a loaded truck coasts down a long steep hill, almost as much work is done by the brakes in holding it as would be done by the engine in pulling it up the same grade. This results in the generation of a large amount of heat in the brake drums and bands. Using the two sets of brakes alternately is recommended to reduce the heating effect.

Two internal brakes placed in the same drum will afford better cooling than one inside brake and one outside brake, if the inside and outside brakes are both applied on the same drum at the same time on a long hill. It is especi-

ally difficult for the heat generated to escape and the linings and drums are liable to become overheated.

On a few trucks where internal brakes are used, the drums are provided with cooling fins similar to those on the cylinders of a motorcycle. Before modern asbestos brake linings had been developed, several European cars employed a water dripping device which operated when the brakes were applied to keep them cool.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

MAINTENANCE

ORAL QUIZ

FOLLOWING LECTURE IV

1. Name the different types of trucks.
2. Explain the digerence between shaft- and chain-drive.
3. What is the F. W. D. truck?
4. What advantage has this truck?
5. Name three standard types of motors.
6. What is the difference between the L- and T-head motors?
7. Name ten parts of an engine.
8. Give their functions.
9. How can a broken bearing be detected?
10. How can poor compression be detected?
11. How can leaky valves be detected?
12. How can worn rings be detected?
13. What is the principle of operation of a four-cycle engine?
14. Name two methods of cooling an engine.
15. What is the advantage of water cooling?
16. How would you grind a valve?
17. Explain how to straighten a bent valve.
18. How would you replace a worn piston ring?
19. Explain the method of replacing main bearings.
20. Explain the method of replacing connecting rod bearings.
21. Explain the method of replacing wrist pin bushing.
22. How would you time the valves?
23. How would you time the ignition?
24. At what point does the inlet valve open?
25. What is accomplished when the spark is advanced?

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

MAINTENANCE

FINAL WRITTEN EXAMINATION

1. Draw a diagram of a simple carburetor.
2. State how this carburetor functions.
3. State as nearly as possible how you would adjust it.
4. Draw a simple ignition system.
5. Write an explanation of what occurs in the induction coil.
6. State the difference between a high and low tension circuit.
7. Explain briefly the important elements of a battery.
8. State the difference between a battery and a magneto current.
9. Is the battery current alternating after it leaves the coil?
10. State the office of a vacuum tank.
11. State two troubles in the vacuum tank and give corrections.
12. Name three systems of supplying fuel to carburetor.
13. State the office of a generator.
14. State the office of a regulator.
15. State the office of a distributor.
16. Draw a sketch of a simple lighting system.
17. Show how a grounded wire robs a lamp of the current.
18. Name four important parts of a transmission.
19. Name four types of rear axles.
20. Name two types of clutches.
21. Why are the brakes equalized?
22. State briefly how to care for springs.
23. Explain how lubricants are used.
24. State the purpose of a lubrication chart.
25. Name an advantage in the use of the chart.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

ADMINISTRATION

LECTURE I

THE SOLDIER

It is the purpose of these lectures to give those soldiers who are chosen to do the different kinds of work in the Motor Transport Corps such information and actual practice as is necessary for the efficient performance of their respective duties.

The training includes a technical course, a general course, drill and actual practice in the particular work assigned.

The course which follows contains such information as will give the student a general knowledge of the army and will help him to understand the particular part which he is to take in this world struggle for liberty.

The modern soldier is a specialist. The science of war has undergone many changes since the days when man went out with spears and armor made of hides and fought with other men in hand to hand combat. The introduction of gun powder with the consequent development of rifles that shoot 750 bullets in a minute and the cannons that shoot many miles with deadly accuracy and the development of transportation facilities, as applied to information, supplies and troops, has made it possible to place vast numbers of soldiers in the field of battle far removed from their home country.

The task of getting them there and maintaining them after they get there, falls upon the nation as a whole and involves the civilians as well as the soldiers themselves.

This mammoth enterprise requires a high degree of organization and specialization. The modern soldier must therefore be a specialist. He must learn his particular task and co-operate with all the others to produce the smoothly operating machine which wins battles and brings victory.

A good soldier, a soldier who serves his country and gains advancement and honor for himself, must have certain qualities.

The first attribute of a good soldier is obedience. "All persons in the military service are required to obey strictly and to execute promptly the lawful orders of their superiors"—A. R. 1. Obedience is the cornerstone of discipline, and it takes discipline to win battles. Prompt, cheerful and efficient obedience helps to bring victory to the army and promotion to the soldier. Disobedience brings defeat to the army and disgrace to the soldier.

He must develop a soldiery bearing. He must walk with his body held erectly, his head up, and take a military pace. His clothes will be clean, well pressed, and in good repair and strictly regulation. His shoes will be shined and his hair neatly trimmed.

He must observe the rules of military courtesy. "Courtesy among military men is indispensable to discipline." It takes many forms and should be practiced at all times. It marks a man as a good soldier among his comrades and particularly among his superiors more quickly than any other one thing.

The salute is one of the marks of courtesy which must be shown by every soldier to his superiors not only in the United States Army and Navy but in the Army and Navy of every other country. When unarmed it is given with the right hand—the right hand is raised smartly to the brim of the hat; fingers together, palm to the left, the forearm at an angle of forty-five degrees, eyes looking directly into the eyes of the person saluted, and is held until the salute is returned or the person has passed. When outdoors and armed with the rifle, the salute will be given by bringing the piece to the right shoulder and the left hand smartly to the small of the stock, palm down; a soldier on sentry or guard duty, armed with a rifle, salutes by coming to "Present Arms." Care should be taken to make the salute in a military manner.

The salute serves two purposes. It is a mark of courtesy among military men and serves as a recognition of the authority which the superior represents. "Day or night, covered or uncovered, whether either or both are in uniform or civilian clothes, salutes shall be exchanged between officers and enlisted men not in a military formation or at drill, work, games or mess, on every occasion of their meeting, passing near or being addressed, the junior in rank or the enlisted man saluting first."

Indoors when not at work, enlisted men rise, uncover, and stand at attention when an officer enters the room, and remain at attention until the officer leaves the room or directs otherwise. If the officer approaches to speak the enlisted man salutes before and after the conversation.

An enlisted man who desires to speak to an officer obtains the authority to do so from the proper person, approaches the officer, stands at attention and salutes. After being recognized by the officer, he states his business briefly and courteously, speaking in the third person. For example, "Sir, Private John Smith desires a transfer." Upon the conclusion of the interview he will salute, execute About Face and leave.

After saluting an officer once the salute need not be repeated if the officer remains in the vicinity. When an officer approaches a number of enlisted men in the open, the first to see him will call "Attention." They will all stand at attention and salute.

When at work, an enlisted man does not salute unless spoken to.

When in formation an enlisted man comes to attention when spoken to by an officer, but does not salute.

When passing within thirty paces of an officer on foot, or when either or both are riding, an enlisted man will salute. The proper saluting distance is at six paces providing they approach that close. If not the salute will be given at the nearest point of approach.

The fourth attribute of a good soldier is to be a good teamworker. No matter how efficiently he may be individually, unless he co-operates with those about him he will fall short of the mark.

He must have courage. Courage to undergo the dangers of battle; courage to do his duty well day by day; courage to withstand the temptations that will cut down his value as a soldier and as a man.

He must be cheerful. A cheerful man in a squad does better work, receives quicker advancement and is a better leader than a "grouch." So for his own sake and for the sake of those about him he must be cheerful.

He must have confidence in himself. Unless a man has confidence in himself he can't expect others to have confidence in him. This confidence should be based upon the knowledge of his ability, and ability in the army is determined by the following five things:

First, CHARACTER. Character is determined by observing a man's personal habits, his dependability, his loyalty, his industry and his consideration of subordinates.

Second, INTELLIGENCE. Intelligence is rated according to a man's ability to learn, his previous education, his accuracy and adaptability.

Third. GENERAL VALUE TO THE SERVICE. Professional knowledge, skill, experience, and success as an organizer and administrator are considered.

Fourth, LEADERSHIP. Leadership depends on a man's force, self reliance, initiative, decisiveness, tact and ability to command the obedience and cooperation of men.

Fifth, PHYSICAL QUALITIES. The matter of physical fitness is a most vital one to the soldier. Success in civil life requires good health. It is even more necessary in the army because of the greater strain placed on a man. It is only the man who is physically fit in every sense of the word that can be under fire for months at a time and come out without his nerves being shattered, or drive his truck through all kinds of weather, long hours each day for weeks at a time, or stand the long marches and the many other tasks required of him in the field.

This sort of fitness is only possible to the men who observe the rules of hygiene and sanitation as laid down for them by the medical department. The soldier who becomes diseased due to his failure to observe these laws is worse than a "slacker." The "slacker" only deprives the government of his services. The sick soldier not only gives no service but takes the time and attention of others, and uses the equipment so badly needed for others who are sick through no fault of their own.

All diseases are caused by taking disease germs into the body in greater quantities than can be overcome by the parts attacked. There are five ways that disease germs may be taken into the body:

1. By swallowing them.
2. By breathing them.
3. By touching them.
4. By the sting of insects.
5. By inheritance.

The more common diseases obtained by swallowing germs are: Typhoid fever, dysentery, cholera and ptomaine poisoning. These diseases can be avoided by:

1. Being innoculated.

2. Eating only pure food. Careful inspections of the manufacture, distribution methods and mess halls insure pure food for the soldier providing he keeps his mess kit and hands clean. Always wash the hands and clean the finger nails before meals. Any food obtained at stores should be carefully cleaned before eating. Food must be protected from flies. The mouth should be washed thoroughly each day and decayed teeth repaired.

3. Drinking pure water. Do not use public drinking cups. Never drink water from strange wells, while on the march. Carry a supply of pure water along in the canteen provided.

The more common diseases obtained by breathing in the germs are: Colds, diphtheria, tonsilitis, grippe, scarlet fever, pneumonia and consumption. To avoid these diseases:

1. Cough or sneeze in a handkerchief.
2. Never spit on the floor.

3. Demand fresh air in sleeping quarters.
4. Dampen the floor before sweeping.
5. Brush the teeth daily.

The more common diseases caught by touching the germs are: Itch, sore eyes, boils, lockjaw, small pox and venereal diseases. To avoid these diseases:

1. Be vaccinated.
2. Use only your own toilet articles.
3. Use only your own pipe.
4. Wash your own clothes, in clean water.
5. Avoid diseased persons.
6. Treat all wounds promptly and keep them clean.
7. Stay entirely away from prostitutes.

The more common diseases caught from the sting of insects are malaria, yellow and dengue fever. To avoid these diseases protect yourself from mosquitoes by bed nets, hat nets and by exterminating the mosquitoes themselves.

However, the most careful soldier cannot altogether avoid taking disease germs into his system. So he must keep himself in such good physical condition that his body will throw off these germs and avoid the disease. To do this the soldier must follow the rules of right living. They are as follows:

1. Cleanliness.
2. Plenty of exercise.
3. Plenty of sleep.
4. To keep the excretory organs operating properly.
5. Temperance in eating and drinking.
6. A clean mind.

Hatred, jealousy, envy and licentiousness have fatal results on one's physical condition.

The soldier who cultivates the above attributes is a good soldier and to him success and honor will surely come.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

ADMINISTRATION

LECTURE II

MILITARY CORRESPONDENCE

CLASSES OF MILITARY CORRESPONDENCE
PARTS OF A LETTER
GENERAL RULES
MILITARY CHANNELS
INDORSEMENTS AND ENCLOSURES
CONFIDENTIAL CORRESPONDENCE
PENALTY ENVELOPES
TELEGRAMS

AIM: To give briefly the prescribed methods of handling military communications.

Correspondence

For convenience, correspondence is usually divided into two classes: general and special.

General correspondence is that which arises from routine operations and consists of notifications of orders, regulations, transmission of periodical reports, maps, etc. Because of its wide circulation, general correspondence is ordinarily printed in pamphlet form.

Special correspondence is that between individuals or between departments and individuals.

Parts of a Letter

Whatever may be the nature of Army Correspondence its form is always the same. A military letter is divided into three parts: the brief, the body and the signature. (M. Q. M. C. 323.)

The brief is so called because it gives a synopsis of the letter by means of which it can be readily filed and referred to. It includes the heading, number of letter, the name of the sender and the person to whom sent. Beginning at the top of the paper in the upper right hand corner is the place it is written and the date. In the upper left hand corner appears the number of the letter. This number is for reference and identification purposes. A short space below and about one and a quarter inches from the left edge of the paper is the word "From" followed by the official designation of the writer or if that is lacking the name, rank and regiment, corps or department. Immediately below is the word "To" followed by the official designation or the name of the person addressed. In the same way the word "Subject" is written below and a brief description of the subject of the letter is given.

The body of the letter is the letter proper.

The signature is that of the writer. If the rank and regiment corps or detachment of the writer have been given in the brief, it should not be added with the signature.

General Rules

A letter is folded into three parts: the upper third containing the brief, is folded toward the back of the letter and the lower third containing the signature is folded up over the body of the letter. The foolscap size is folded into four parts.

Only one side of the paper should be used. A margin of about an inch and a quarter should be kept on both sides.

The ceremonial address "Sir" and all salutations are omitted.

The body of the letter is single spaced. If more than one paragraph they are numbered consecutively and a double space left between them.

Every statement should be as brief and concise as possible.

Military Channels

Unlike the business letter of the commercial world, the military letter does not always proceed directly from the writer to the person to whom it is addressed. Communications, whether from a superior to a subordinate or vice versa pass through the intermediate commanders. This mode of transmittal is known as Military Channels.

Any member of a company wishing to communicate with his Company Commander must first obtain permission from the first sergeant, one of whose duties is to see that the Company Commander is not annoyed with trivial matters which the Sergeant himself is able to settle.

In a post, if an enlisted man desires to communicate with the Commanding Officer, he addresses the letter to his Company Commander, or to the Commanding Officer (through military channels). Then the Company Commander, if the letter refers to a matter that he has no authority to handle, indorses it and forwards it by the first sergeant along with the morning report to regimental headquarters. The Commanding Officer of the regiment indorses the letter in turn and if unauthorized to dispose of it, forwards it to post or division headquarters (depending upon the form of the organization at the post). There it is first handled by the Sergeant Major, who is the principal Assistant to the Adjutant, being responsible to him for the proper care and disposition of all records and correspondence at headquarters. The letter then goes to the Adjutant who approves or disapproves it by indorsement, and passes it back through the same channels, provided the communication covers a case upon which he has instructions and authority for action from the Commanding Officer. If the letter covers a special case over which he has no authority, he submits it to the Commanding Officer for action. When this is completed, the same disposition is made of the letter as before stated.

Correspondence in the field goes through the following military channels:

From Company Headquarters to Regimental Headquarters; to Division Headquarters to Commander-in-Chief of the Field Forces.

All communications from officers and enlisted men, outside of the War Department, intended for the Secretary of War or any bureau or office of the War Department, are addressed to the Adjutant General of the Army, except where special authority has been granted for direct correspondence. Similarly all correspondence of the War Department with the Army is through or by the

Adjutant General of the Army. The Adjutant General makes the proper disposition of any papers coming to his office. There is, however, no objection to a request being embodied in any communication sent to his office that the papers be acted upon or disposed of in a specific way.

Unimportant and trivial communications need not be forwarded to the Adjutant General of the Army simply because addressed to him. Department, district, and brigade commanders decide whether a communication is of sufficient importance to be forwarded. All communications should be returned through the channels by which they are forwarded. If an enlisted man does not know the exact method of addressing an official communication, he should address it to his Company Commander who will, if he approves the letter, forward it through the proper channels.

Indorsements

The above paragraph shows the reason for indorsements. An indorsement is a written expression of opinion upon the subject of the letter by an officer who receives an official communication for further transmittal or final decision.

The first indorsement should begin about one half inch below the rank after the signature of the writer of the letter, and succeeding indorsements should follow one another serially with a space of about one-half inch between indorsements.

Indorsements are numbered serially and show the date, place, and to whom written, with the signature of the writer. In making indorsements of a routine nature, the attachment of the initials is sufficient for the signature. (M. Q. M. C. 323.)

Inclosures

It sometimes happens that in addition to indorsements, supporting evidence in the form of records, affidavits, etc., is required. These are called inclosures, and they should be numbered and given proper office marks. (M. Q. M. C. 323.)

Enclosures, together with the number of the indorsement to which they belong, should be noted on the back of the lower fold of the first sheet of the original communication. The total number of the inclosures accompanying a paper should be noted at the foot of each indorsement thereon. (Bulletin No. 24, W. D. 1912.)

Confidential Correspondence

A document or map marked "Secret" is for the personal information of the individual to whom it is officially entrusted, and of those officers under him whose duties it affects. The officer to whom it is entrusted is personally responsible for its safe custody, and should see that its contents are disclosed to those officers mentioned above, and to them only. The existence of such a document or map must not be disclosed by the officer to whom it is entrusted nor by his officers without the sanction of superior military authority. No document or map marked "secret" should be taken into the front line trenches in the theatre of war. A document or map marked "secret" even though it may bear other classifying marks, such as "confidential" or "for official use only" must, nevertheless be regarded as "secret" within the meaning of this paragraph.

A document or map marked "confidential" is of less secret a nature than one marked "secret," but its contents will be disclosed only to persons known to be authorized to receive them or when it is obviously in the interest of the public service that they receive them. (M. Q. M. C. 292.)

The information contained in a document or map marked "for official use only" must NOT be communicated to the public or to the press, but may be communicated to any person known to be in the service of the United States, simply by virtue of his official position.

Documents and maps classed as "secret" or "confidential" must NOT be referred to in any catalogue or publication which is not itself a document marked "secret" or "confidential" as the case may be. An officer or soldier who communicates information contained in a document or map marked "secret" or "confidential" or "for official use" must at the same time inform the person or persons to whom he communicates the information that it is "secret" or "confidential" or "for official use only," as the case may be. The only legitimate use an officer or soldier may make of documents or information of which he becomes possessed in his official capacity is for the furtherance of the public service in the performance of his duty. Publishing official documents or information or using them for personal controversy, or for any private purpose without due authority, will be treated as a breach of official trust and may be punished under the Articles of War, or under Section I. Title of the espionage. (000 72 A. G. O.) (M. Q. M. C. 292.)

Penalty Envelopes

Official communications and other mailable matter relating exclusively to the public business will be transmitted through the mails free of postage if covered by the "Penalty Envelope." Envelopes for official mail have "War Department," the name of the bureau or office of the department, and "Official Business" printed in the upper left hand corner and in the upper right hand corner the warning "Penalty for Private Use $300.00" hence the name "Penalty Envelopes." (M. Q. M. C. 324, 333.)

Par. 835, A. R. defines official information as "that which is intended for the performance of official duties only." Information intended for the furtherance of private interests or aims, even when called for by an officer or official of the War Department is classed as private information and must be covered by the prescribed postage. In writing to any person from whom official information is desired, it is permissable to enclose a penalty envelope for the return of that information. This permission, however, does not include the furnishing of penalty envelopes to merchants or dealers to cover the transmission of public property or the return of official vouchers. (Par. 837, A. R.)

Telegrams

The telegraph and cable service will be used only in case of urgent necessity or when delay will hinder the business of the service and in cases where delay caused by using the mail will be prejudicial to the best interests of the service. Day telegrams should be sent only when night telegrams will not serve the purpose. Except in extreme necessity night telegrams should not be sent when the mail can be delivered the following morning. Night telegrams should be plainly indicated by the words "Night Telegram" being stamped thereon. When it is practicable to do so, telegrams from one office may be consolidated at the close of business and made the subject of one telegram, where such con-

solidation can be made without embarrassing the interests of the service. (Par. 334, M. Q. M. C.)

Government blanks should be used when practicable when sending official telegrams by those in the service of the War Department authorized to send such telegrams. They should be marked "Government Paid" but never "Government Collect." Commercial blanks, if used officially should also be marked "Government Paid" on the face of the blank. Accounts for telegrams as military business, prepared on the prescribed form in the name of the telegraph company rendering the service and accompanied by the original telegrams will be paid by the Depot Quartermaster, Washington, D. C.

Fort Niagara, N. Y.,

Jan. 7, 1916.

FROM: Mechanic James Andrews, Co. "A," 1st Inf.

TO: Comdg. Genl., Eastern Dept.

SUBJECT: Transfer.

1. I would request to be transferred to Co. "B," 2nd Inf.
2. My reasons for requesting this transfer are that I served an enlistment in that company, which is now stationed near my home, Sackets Harbor, N. Y.
3. I am serving my second enlistment period.
4. Date of present enlistment, Apr. 1/14.
5. I am enclosing a letter from my mother, who is an invalid, asking me to make the transfer, if possible.

JAMES ANDREWS.

1 Incl.

2123. 1st Ind.

Co. "A," 1st Inf., Fort Niagara, N. Y., Jan. 9/16. To Post Commander.

1. Character of soldier is "very good."
2. He is single.
3. Three years, Co. "B," 2nd Inf., March 15/14. Serving his second enlistment period since Apr. 1/14.
4. Soldier has no convictions by court-martial; he is not under charge nor in confinement.
5. Soldier has sufficient funds to defray expenses incident to transfer.
6. Has not previously been transferred during his current enlistment.
7. Physical condition—good.
8. Authorized strength of company is 100; actual strength is 95.

HENRY A. DUBBS,
Capt., 1st Inf., Comdg.

1 Incl.

4356. 2nd Ind.

Hq. Fort Niagara N. Y., Jan. 9/16. To C. O., Madison Bks., N. Y.
Approved.

C. H. WELLER,
Col., 1st Inf., Cmdg.

1 Incl.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

ADMINISTRATION

LECTURE III

MILITARY LAW

A. Kinds of Military Jurisdiction.

B. Books Describing Military Jurisdiction.

1. U. S. Army Regulations.
2. Manual for Courts-Martial.
3. Articles of War.
4. Manual of Interior Guard Duty.
5. Field Service Regulations.

C. Courts-Martial.

1. Kinds.
2. Appointment.
3. Personnel.
4. Jurisdiction.
5. Punishments.

In civil life, conduct is regulated by the laws made in Congress, Legislatures, and governing bodies of smaller political organizations, such as the counties and cities and enforced by the police and when necessary by the aid of the militia or regular army. Offenders are tried by courts established for the purpose and punished according to the provisions of the law.

In the army conduct is regulated by a different set of laws designed for the particular purpose of controlling those under military jurisdiction. These laws are enforced by military authorities and offenders are tried by courts of a particular kind known as "Courts-Martial."

Military jurisdiction is in force at all times in the army and when special needs arise it is extended over civilians. It is divided into four classes.

1st—*Military Government.*—This is the form of government established in time of war over a conquered territory and its inhabitants. The laws are such as will get the maximum amount of assistance from the conquered people for the purpose of continuing the war. They are enforced by soldiers and offenders are tried by military commissions and provost courts.

2nd—*Martial Law at Home.*—This form of military jurisdiction is used to control the conduct of communities when the civil authorities are unable or for any reason do not exercise the necessary control. The laws are made and enforced by military authorities.

3rd—*Martial Law in the Army.*—This form of military jurisdiction is used to control persons in the military service who are in a state of insurrection or rebellion.

4th—*Military Law.*—Military law is the legal system that regulates the government of the military establishments. It contains the rules and regulations by which every soldier is governed. It is both written and unwritten. The sources of written military law are the Articles of War enacted by Congress,

the Army Regulations and General and Special Orders and decisions promulgated by the War Department, Post and other Commanders.

The books in which these laws, orders, rules, and regulations may be found are: Army Regulations, Manual for Courts-Martial, Manual of Interior Guard Duty, Field Service Regulations, and for the Quartermaster Corps, in the Manual for the Quartermaster Corps, U. S. Army.

Army Regulations.—In general the A. R. cover all matters pertaining to military discipline, rank of procedure, promotions, transfers, leaves of absence, furloughs, responsibility and accountability, territorial divisions of the country and the various departments of the Army—in short all matters touching on the instruction, organization and regulation of the military service. Every officer and enlisted man should know those parts which directly affect his position, duties and responsibility.

Article I is of particular interest. It covers the matters of military discipline. Paragraph 1 provides that "all persons in the military service are required to obey strictly and execute promptly the lawful orders of their superiors." Paragraph 2 provides that "military authority will be exercised with firmness and kindness and justice." Paragraph 3 insures the self-respect of the enlisted men by providing that "superiors are forbidden to injure those under their authority by tyrannical or capricious conduct or abusive language." Paragraph 4 states that "courtesy among military men is indispensable to discipline" and that it will be extended on all occasions. Paragraph 5 forbids deliberations among military men conveying praise or censure towards others in the military service.

The regulations when obeyed will insure discipline without which an army cannot be victorious.

THE MANUAL OF INTERIOR GUARD DUTY and THE FIELD SERVICE REGULATIONS will be discussed in detail in later lectures.

THE ARTICLES OF WAR are 121 in number and describe the particular offenses which are punishable by Courts-Martial and prescribe the authority of the court to impose punishment in each case. They are to be found in the Manual for Courts-Martial.

The following table will show some of the more common offenses, the punishment to be imposed, and the number of the Article.

OFFENSE	PUNISHMENT IN THE TIME OF WAR	Art. No.
Spies	Death	82
Desertions	Death or as a Court Martial directs	58
Advising or aiding another to desert	" " "	59
Assaulting or wilfully disobeying a superior officer	" " "	64
Mutiny or sedition	" " "	66
Misbehavior before enemy	" " "	75
Improper use of countersign	" " "	77
Forcing a safeguard	" " "	78
Aiding the enemy	" " "	81
Insubordinate conduct toward non-commissioned officers	As a Court Martial may direct	65
Absence without leave	" " "	61
Quarrels, frays, disorders	" " "	68
Drunk on duty	" " "	85
General article	" " "	96

The Manual for Courts-Martial stipulates the manner of securing justice for soldiers accused of violating the Articles of War.

There are three kinds of Courts-Martial—general, special and summary. The following table will show the main differences between them and the essential features of each.

KIND	Appointed By	Personnel	Jurisdiction	Maximum Punishment
General	C. O. of division or larger unit.	5 to 13 commissioned officers.	All persons in the military service.	Death.
Special	C. O. of regiment or larger unit.	3 to 5 commissioned officers.	All persons in the military service except officers.	6 mos. confinement 6 mos. pay.
Summary	C. O. of detached Co. or larger unit up to regiment.	One commissioned officer.	All persons in the military service except officers and non-commissioned officers who object thereto.	3 mos. confinement and loss of 3 mos. pay.

Only a general court-martial can impose a dishonorable discharge.

Besides the court itself every proceeding requires a judge advocate who is appointed by the same authority who appoints the court. The judge advocate represents the government, swears in the court, and is sworn in by the president of the court. His work corresponds to that of the prosecuting attorney in a civil court. He examines witnesses for the prosecution and cross examines witnesses for the defense.

The accused has the right of counsel. Any commissioned officer may be appointed to act as his counsel upon the request of the accused or the accused may hire a civil attorney for that purpose. The counsel advises the accused, examines the witnesses for the defense and cross examines the witnesses for the prosecution.

The accused may challenge the appointment of any member of the court and if it is shown that such member for any reason would not give an unbiased judgment he will be replaced.

All proceedings will be made a matter of record by the clerk of the court.

After hearing has been completed the court votes in the order of rank, the juniors voting first, on the charge of guilty or not guilty, and then on the punishment to be imposed. A majority vote decides the case except in the case of a capital crime, when it requires two-thirds majority to convict.

The decision of the court is subject to review by the appointing authority and does not go into effect until approved by that authority.

The organization of the court and the procedure is such that impartial justice will be given and the accused may be sure of fair treatment throughout.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

ADMINISTRATION

LECTURE IV

GUARD DUTIES

OFFICERS.

Officer of the Day.
Commander of the Guard.

ENLISTED PERSONNEL.

Sergeant of the Guard.
Corporal of the Guard.
Sentinels.
Musicians.

COUNTERSIGNS AND PAROLES.
GENERAL AND SPECIAL ORDERS.
GUARDING PRISONERS.

FLAGS.

Garrison.
Post.
Storm.

It is probable that most soldiers will at one time or another be called upon to perform guard duty, hence the importance of this subject. Proficiency in these duties, however, cannot be acquired by any short cut methods, but can be attained by steady and untiring efforts to master the rules of the Manual of Interior Guard Duty and by actual experience in the capacity of sentinels.

Officer of the Day.—There is an officer of the day of each guard, who is responsible for the proper performance of duty by the guard assigned to him and for the enforcement of all police regulations. He is responsible to the Commanding Officer.

The Officer of the Day prescribes patrols and orders inspections to be made by officers and non-commissioned officers of the guard whenever he deems necessary. In case of alarm he takes the steps necessary for protection of life and property. He must keep the commander of the guard informed of his whereabouts at all times, in order that he may be reached in case of emergency.

Officers of the guard are assigned to it in accordance with the strength of the guard. If it be large enough each guard is assigned a commander and such subordinate officers as may be necessary. Officers of the guard must remain constantly with their guards.

Commander of the Guard.—The commander of the guard inspects the sentinels at reveille and retreat and at any other time he may deem necessary to assure himself that they are in proper condition. He questions his non-commissioned officers and sentinels regarding instructions they may have re-

ceived from the old guard and supervises patrols, and visits of inspection ordered by the Officer of the Day.

Sergeant of the Guard.—The senior non-commissioned officer of the guard always acts as Sergeant of the Guard and if there be no Officer of the Guard performs the duties prescribed for the commander of the guard.

The position of the Sergeant of the Guard is difficult and responsible. He has general supervision over the non-commissioned officers, musicians, and privates of the guard and must be thoroughly familiar with all their orders and duties.

He is responsible for all property under charge of the guard, for policing of the guardhouse, including the grounds and the prison cells. He reports to the commander of the guard any suspicious occurrence, warns him of the approach of armed troops and sends to him all persons arrested by the guard. He is directly in charge of the entire guard, supervising and inspecting its work and is responsible to the commander of the guard.

Corporal of the Guard.—The corporal of the guard is assigned to a relief consisting of the sentinels who are to guard certain posts. He sees that the relief is properly posted, that orders are properly transmitted from the old sentinel to the new. He inspects the members of his relief in the performance of their orders and duties. He assigns posts to each member of his relief. After posting the guards the corporal makes a report in duplicate concerning all members of his relief, including himself, giving the numbers of the relief, the name, company, post to which each is assigned. One copy of this report is given to the sergeant, the other is retained.

Each corporal must know all special and general orders pertaining to his relief. He will see that each one understands and transmits such orders in detail to his successor. The corporal is stationed near his relief and is called in all cases not covered by instructions.

Musicians of the Guard.—The musicians of the guard will sound calls as prescribed by the commanding officer.

Should the guard be turned out for national or regimental colors or standards, uncased, the field music of the guard will, when the guard present arms, sound "To the Colors" or "To the Standard," or if for any person entitled thereto, the march, flourishes, or ruffles, prescribed in paragraphs 375, 376, 377, A. R.

Countersigns and Paroles.—Forty-fourth Article of War. Any person belonging to the armies of the United States who makes known the watchword to any person not entitled to receive it according to the rules and discipline of war, or presumes to give a parole or watchword different from that which is received, shall suffer death or such other punishment as a court-martial may direct.

The Countersign is a word given daily from the principal headquarters of a command to aid guards and sentinels in identifying persons who may be authorized to pass at night.

It is given to such persons as may be authorized to pass and repass sentinels' posts during the night, and to officers, and non-commissioned officers and sentinels of the guard.

The parole is a word used as a check on the countersign in order to obtain a more accurate identification of persons. It is imparted only to those who are entitled to inspect guards and to commanders of guards.

Thirty-sixth Article of War.—No soldier shall hire another to do his duty for him.

Privates are assigned to reliefs by the commander of the guard, and to posts, usually by the corporal of their relief. They will not change from one relief or post to another during the same tour of guard duty unless by proper authority.

Orders of Sentinels.—Orders for sentinels are of two classes: General orders and special orders. General orders apply to all sentinels. Special orders relate to particular posts and duties.

Sentinels will be required to memorize the following:

My general orders are:

1. To take charge of this post and all government property in view.
2. To walk my post in a military manner, keeping always on the alert and observing everything that takes place within sight or hearing.
3. To report all violations of orders I am instructed to enforce.
4. To repeat all calls from posts more distant from the guardhouse than my own.
5. To quit my post only when properly relieved.
6. To receive, obey, and pass on to the sentinel who relieves me all orders from the commanding officer, officer of the day, and officers and non-commissioned officers of the guard only.
7. To talk to no one except in line of duty.
8. In case of fire or disorder to give the alarm.
9. To allow no one to commit a nuisance on or near my post.
10. In any case not covered by instructions to call the corporal of the guard.
11. To salute all officers, and all colors and standards not cased.
12. To be especially watchful at night, and during the time for challenging to challenge all persons on or near my post, and to allow no one to pass without proper authority.

Sentinels posted at the guard will be required to memorize the following:

Between reveille and retreat to turn out the guard for all persons designated by the commanding officer, for all colors and standards not cased, and in time of war for all armed parties approaching my post, except troops at drill and reliefs and detachments of the guard.

At night, after challenging any person or party, to advance no one, but call the corporal of the guard, repeating the answer to the challenge.

Guarding Prisoners.—The sentinel at the post of the guard has charge of the prisoners except when they have been turned over to the prison guard or overseers.

1. He will allow none to escape.
2. He will allow none to cross his post leaving the guardhouse except when passed by an officer or non-commissioned officer of the guard.
3. He will allow no one to communicate with prisoners without permission from proper authority.
4. He will promptly report to the corporal of the guard any suspicious noise made by the prisoners.
5. He will be prepared to tell whenever asked how many prisoners are in the guardhouse and how many are out at work or elsewhere.

Whenever prisoners are brought to his post returning from work or elsewhere, he will halt them and call the corporal of the guard, notifying him of

the number of prisoners returning. Thus: "Corporal of the guard, (so many) prisoners."

He will allow no prisoners to pass into the guardhouse until the corporal of the guard has responded to the call and ordered him to do so.

When not engaged in the performance of a specific duty, the proper execution of which would prevent it, a member of the guard will salute all officers who pass him. This rule applies at all hours of the day and night except in the case of mounted sentinels armed with a rifle or pistol, or dismounted sentinels armed with a pistol, after challenging.

Sentinels will salute as follows: A dismounted sentinel armed with a rifle or saber, salutes by presenting arms; if otherwise armed, he salutes with the right hand.

Flags.—The garrison flag will have 38 feet fly and 20 feet hoist. It will be furnished only to posts designated in orders from time to time from the War Department, and will be hoisted only on holidays and important occasions.

The post flag will have 19 feet fly and 10 feet hoist. It will be furnished for all garrison posts and will be hoisted in pleasant weather.

The storm flag will have 9 feet 6 inches fly and 5 feet hoist. It will be furnished for all occupied posts for use in stormy and windy weather. It will also be furnished to national cemeteries. (A. R. 223.)

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

ADMINISTRATION (FOLLOWING LECTURE IV)

TYPICAL QUIZ QUESTIONS

Motor Truck Drivers' Course

1. How does a soldier on sentry or guard duty armed with a rifle salute?
2. Name the five ways in which diseases are contracted.
3. Name the parts of a letter.
4. What are military channels?
5. What is an indorsement?
6. Name the three classes of confidential communications.
7. Give three rules for the use of telegrams in government communications.
8. What is meant by military government?
9. Under what circumstances is martial law at home declared?
10. What are the Articles of War?
11. Give the powers of a summary court-martial.
12. May a special court-martial try officers; non-commissioned officers?
13. What are the duties of the officer of the day?
14. What are the duties of a corporal of the guard?
15. Give the twelve General Guard Orders.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

ADMINISTRATION

LECTURE V

CARE OF ARMS AND EQUIPMENT

General Care of Rifle Cartridges

Ball
Blank
Guard
Dummy

Cleaning Rifle to Remove

Powder fouling
Metal fouling

Solutions Used

Soda
Swabbing
Standard Metal-fouling
Nitro-Solvent

Care of Leather

The rifle now used by our Army is the model 1917 and is frequently referred to as the Enfield rifle as it is somewhat like the Enfield rifle and embodies some of the principal features of that rifle.

It has a range of almost two miles, but the best results are obtained at a range of not over 1200 yards.

The only parts of a rifle that an enlisted man is permitted to take apart are the bolt mechanism, and the magazine mechanism. It is essential that he learns to do this, for he must know how, in order to keep his rifle clean. Never remove the hand guard or the trigger guard, nor take the sights apart unless you have special permission from a commissioned officer.

Every part of the rifle must be kept free from rust, dust and dirt. A dirty or dusty rifle is a sure sign that a soldier does not realize the value of his weapon, and that his training is not complete.

The rifle you are armed with is the most accurate in the world today. If it is not kept properly clean, and is allowed to get dirty or rusty, it will deteriorate in its accuracy and no subsequent care will restore it to its original condition. The most important part of the rifle to keep clean is the bore. If the rifle is left over night after having been fired in the afternoon, it will be badly rusted in the morning. Therefore, it is essential that the rifle be cleaned not later than the evening of the day it was fired. The fouling of the blank cartridge is as dangerous to the bore as the fouling of the ball cartridge.

Never polish any part of the rifle that is blued. If rust appears, remove it by rubbing it with oil. Never use emery paper, pomade, or any preparation that cuts or scratches, to clean any part of the rifle.

To beautify and preserve the stock, rub it with raw linseed oil. The use of any other preparation on the stock is forbidden.

Your rifle will be your comrade and life preserver throughout the service, and you should always handle it with care. Don't stand it up against anything so that it rests against the front sight. Don't leave a stopper or rag in the bore; it will cause rust to form at that point. It may also cause the gun barrel to burst if a shot is fired before removing it. Guard the sights and muzzle carefully from any blow that might injure them. The front sight cover is especially necessary to protect the sight while the rifle is being carried in the scabbard by mounted men. In coming to "Order Arms" lower the rifle gently to the ground. When there is a cartridge in the chamber, the piece is always carried locked, except when on the firing line. In this position, the safety lock should be kept turned full to the rear, since, if it is turned to the front nearly to the "ready" position and the trigger is pulled, the rifle will be discharged.

Cartridges cannot be loaded from the magazine unless the bolt is drawn fully to the rear. When the bolt is closed or partly open, the safety lock may be turned up or down as desired; but if the bolt is drawn fully to the rear, the magazine cannot be cut off unless the top cartridge or the follower is pressed down slightly and the bolt is pushed forward so that the safety lock may be turned off.

Should your rifle misfire, do not open bolt immediately, as it may be a hang fire. Misfire is often due to the fact that the bolt handle was not fully pressed down. Sometimes in pulling the trigger the soldier raises the bolt without knowing it.

On being relieved from duty unload arms before going to barracks or tents unless otherwise ordered.

There are four types of cartridges:

(1) *The ball cartridge* consists of the brass case or shell, the primer, the charge of smokeless powder, and the bullet. The bullet has a sharp point, is composed of a lead core and a jacket of cupro-nickel, and weighs 150 grains. The bullet of this cartridge, when fired from the rifle, starts with an initial velocity at the muzzle of 2700 feet per second.

(2) *The blank cartridge* contains a paper wad instead of a bullet. It is dangerous up to 100 feet. Firing with blank cartridges at a represented enemy at less than 100 feet is prohibited.

(3) *The guard cartridge* has a smaller charge of powder than the ball cartridge, and five cannelures encircle the body of the shell at about the middle to distinguish it from the ball cartridge. It is intended for use on guard or in riot duty, and gives good results up to 200 yards. The range of 100 yards requires a sight elevation of 450 yards, and the range of 200 yards requires an elevation of 650 yards.

(4) *The dummy cartridge* is tin plated and the shell is provided with six longitudinal corrugations and three circular holes. The primer contains no percussion composition. It is intended for drill purposes to accustom the soldier to the operation of loading the rifle.

All cartridges are secured five in a clip to enable five cartridges to be inserted in the magazine at one motion. Sixty ball cartridges in 12 clips are packed in a cloth bandolier to facilitate issue and carrying. When full the bandolier

weighs about 3.88 pounds. Bandoliers are packed 20 in a box, or 1200 rounds in all. The full box weighs 90 pounds.

Keep the Working Parts Oiled.—In every company there should be at least one copy of the Manual of the Ordnance Department, entitled, "Description and Rules for the management of the U. S. Magazine Rifle." This manual gives the name and cut of every part of the rifle, explains the use, how to take the rifle apart and to care for it, and also gives much other valuable and interesting information.

Cleaning the Rifle.—The proper care of the bore requires conscientious and careful work; but it pays well in the attainment of reduced labor in the cleaning, prolonged accuracy, life of the barrel and better results in combat. Briefly stated, the care of the bore consists in removing the fouling resulting from firing, to obtain a chemically clean surface, and in coating this surface with a film of oil to prevent rusting. The fouling which results from firing is of two kinds: One, the products of combustion of the powder; the other, cupro nickel scraped off (under the abrading action of irregularities or grit in the bore). Powder fouling, because of its acid reaction, is highly corrosive; that is, it will induce rust and must be removed. Metal fouling of itself is inactive, but may cover powder fouling, and prevent the action of cleaning agents, until removed, and when accumulated in noticeable quantities, it reduces the accuracy of the rifle.

Powder fouling may be readily removed by a scrubbing with hot soda solution, but this solution has no effect on the metal fouling of cupro nickel. It is necessary therefore to remove all metal fouling before assurance can be had that all powder fouling has been removed and that the bore can be safely oiled. Normally, after firing a rifle, the barrel of which is in good condition, the metal fouling is so slight as to be hardly perceptible. It is merely a smear of infinitesimal thickness, easily removed by solvents of cupro nickel. However, owing to the pitting, to the presence of dust and other abrasives, metal fouling may occur in clearly visible flakes or patches of much greater thickness, much more difficult to remove.

In cleaning the bore after firing, it is well to proceed as follows: Swab out the bore with soda solution to remove powder fouling. A convenient method is to insert the muzzle of the rifle into the can containing the soda solution, and with the cleaning rod inserted from the breach to pump the barrel a few times. Remove and dry with a couple of patches. Examine the bore to see that there are in evidence no patches of metal fouling, which, if present, can be readily detected by the naked eye; then swab out with the swabbing solution, a diluted metal-fouling solution. The amount of swabbing required with the swabbing solution can be determined only by experience, assisted by the color of patches. Swabbing should be continued, however, as long as the wiping patch is discolored by a bluish green stain. Normally a couple of minutes' work is sufficient. Dry thoroughly and oil.

The proper method of oiling a barrel is as follows: Wipe the cleaning rod dry; select a clean patch and thoroughly saturate it with sperm oil or warmed cosmic, being sure that the cosmic has penetrated the patch; scrub the bore with the patch, finally drawing the patch smoothly from the muzzle to the breech, allowing the cleaning rod to turn with the rifling. The bore will be found now to be smooth and bright, so that any subsequent rust and sweating can be easily detected by inspection.

If patches of metal fouling are found upon visual inspection of the bore, the standard metal fouling solution prepared as hereinafter prescribed must be used. After scrubbing out with soda solution, plug the bore from the breech

with a cork at the front end of the chamber or where the rifling begins. Slip a 2 inch section of rubber hose over the muzzle down to the sight and fill with the standard solution to at least one-half inch above the muzzle of the barrel. Let it stand for 30 minutes. Pour out the standard solution, remove hose and breach plug, and swab out thoroughly with soda solution, to neutralize and remove all trace of ammonia and powder fouling. Wipe the barrel clean, dry, and oil it. With few exceptions one application is sufficient, but if all fouling is not removed as determined by careful visual inspection of the bore and of the wiping patches, repeat as described above.

After a proper cleaning with either the swabbing solution or the standard solution as has just been described, the bore should be clean and safe to oil and put away; but as a measure of safety, a patch should always be run through the bore on the next day and the wiping patch examined to insure that cleaning has been properly accomplished. The bore should then be oiled, as described above.

If the swabbing solution or the standard metal-fouling solution is not available, the barrel should be scrubbed, as already described, with the soda solution, dried, and oiled with light oil. At the end of 24 hours it should again be cleaned, when it will usually be found to have "sweated," that is, rust having formed under the smear of metal-fouling where powder fouling was present, the surface is puffed up. Usually, a second cleaning is sufficient, but to insure safety it should again be examined at the end of a few days, before final oiling. The swabbing solution should always be used, if available, for it must be remembered that each puff when the bore "sweats" is an incipient rust pit.

A dry, clean surface having been obtained, to prevent rust it is necessary to coat every portion of this surface with a film of neutral oil. If the protection required is but temporary and the arm is to be cleaned or fired in a few days, sperm oil may be used. This is easily applied and easily removed, but has not sufficient body to hold its surface for more than a few days. If rifles are to be prepared for storage or shipment, a heavier oil, such as cosmic, must be used.

Where arms are being prepared for storage or shipment they should be cleaned with particular care, using the metal fouling solution, as described above. Care should be taken, insured by careful inspection on succeeding day or days, that the cleaning is properly done and all traces of ammonia solution removed. The bore is then ready to be coated with cosmic. At ordinary temperatures, cosmic is not fluid. In order to insure every part of the surface being coated with a film of oil, the cosmic should be warmed. Apply the cosmic first with a brush, then with the breech plugged, fill the barrel to the muzzle, pour out the surplus, remove the breech block, and allow it to drain. It is believed that more rifles are ruined by improper preparation for storage, than from any other cause. If the bore is not clean when oiled, that is, if powder fouling is present or rust has started, a half inch of cosmic on the outside will not stop its action, and the barrel will be ruined. Remember that the surface must be perfectly cleaned before the heavy oil is applied. If the instructions as given above are carefully followed, arms may be stored for years without harm.

Preparation of Solution

Soda Solution.—This should be a saturated solution of sal soda (bicarbonate of soda). A strength of at least 20 per cent is necessary. The spoon referred to in the following directions is the model 1910 spoon issued in the mess outfit.

Sal soda, one-fourth pound, or four heaping spoonfuls. Water, 1 pint or cup, model 1910, to upper rivets. The sal soda will dissolve more readily in hot water.

Swabbing Solution.—Ammoniam persulphate, 60 grains, one-half spoonful smoothed off. Ammonia, 28 per cent, 6 ounces, or three-eighths of a pint, 12 spoonfuls. Water, 4 ounces, or one-fourth pint, or 8 spoonfuls. Dissolve the ammoniam sulphate in the water and add the ammonia. Keep in a tightly corked bottle, pour out only what is necessary at the time, and keep the bottle corked.

Standard Metal-Fouling Solution.—Ammonium persulphate, 1 ounce, or two medium heaping spoonfuls. Ammonium carbonate, 200 grains, or 1 heaping spoonful. Ammonia, 28 per cent, 6 ounces, or three-eighths pint, or 12 spoonfuls. Water, 4 ounces, or one-fourth pint, or 8 spoonfuls.

Powder the persulphate and carbonate together, dissolve in the water, and add the ammonia, mix thoroughly and allow the mixture to stand for one hour before using. It should be kept in a strong bottle, tightly corked. The solution should not be mixed with unused solution, but should be bottled separately. The solution, when mixed, should be used within 30 days. Care should be exercised in mixing and using this solution to prevent injury to the rifle. An experienced noncommissioned officer should mix the solution and superintend its use.

Neither of these ammonia solutions have any appreciable action on steel when not exposed to the air, but if allowed to evaporate on steel they attack it rapidly. Care should therefore be taken that none spills on the mechanism and that the barrel is washed out promptly with soda solution. The first application of soda solution removes the greater portion of the powder fouling and permits a more effective and economical use of the ammonia solution. These ammonia solutions are expensive and should be used economically.

It is a fact recognized by all that a highly polished steel surface rusts much less easily than one which is roughened. Also that a barrel which is pitted fouls much more rapidly than one which is smooth. Every effort, therefore, should be made to prevent the formation of pits, which are merely enlarged rust spots and which not only affect the accuracy of the arm, but increases the labor of cleaning.

The chambers of rifles are frequently neglected because they are not readily inspected. Care should be taken to see that they are cleaned as thoroughly as the bore. A roughened chamber lessens greatly the rapidity of fire and not infrequently causes shells to stick.

A cleaning rack should be provided for every barrack. Rifles should always be cleaned from the breech, thus avoiding possible injury to the rifling at the muzzle which would affect the shooting adversely. If the bore for a length of six inches at the muzzle is perfect a minor injury near the chamber will have little effect on the accuracy of the rifle. The rifle should be cleaned as soon as the firing for the day is completed. The fouling is easier to remove then, and if left longer it will corrode the barrel.

The principles as outlined above apply equally well for the care of the barrel of the automatic pistol. Special attention should be paid to the cleaning of the chamber of the pistol, using soda solution. It has been found that the chamber pits readily if it is not carefully cleaned, with the result that the operation of the pistol is made less certain.

Care of Leather

General.—Because of the value of leather equipment and its rapid deterioration if neglected, the proper care of leather is most important.

Materials.—Two agents are necessary to the proper cleaning of leather—a cleaning agent and an oiling agent.

The cleaning agent issued by the Ordnance Department is castile soap; the oiling agents are neat's-foot oil and harness soap.

The soap cleans the surface of the leather, and removes from the surface pores of the leather, dirt, sweat, and other foreign matter, so that the oil can more readily penetrate the pores and saturate the fibers thus making the leather pliable and elastic.

Cleaning.—Daily, or as often as used, leather equipment should be wiped off with a cloth slightly dampened in water, merely to remove mud, dust or other foreign substances.

This daily care will do much to maintain the appearance of the equipment, but it is, however, insufficient of itself to properly preserve it.

Leather should never be cleaned by immersing in water or holding under a hydrant.

At intervals of from one to four weeks, depending upon the circumstances, it is essential that the equipment be thoroughly cleaned in accordance with the following instructions:

(*a*) Separate all parts, unbuckle straps, remove all buckles, loops, etc., where possible.

(*b*) Wipe off all surface dust and mud with a damp (not wet) sponge. After rinsing out the sponge, a lather is made by moistening the sponge in clear water, squeezing it out until nearly dry, and rubbing it vigorously upon castile soap. When a thick, creamy lather is obtained, thoroughly clean each piece of the equipment without neglecting any portion. Each strap should be drawn its entire length through the lathered sponge so as to actually remove the salt, sweat, and dirt from each leather piece.

(*c*) After again rinsing the sponge make a thick lather as described above with saddle soap. Go over each separate piece, thoroughly working the lather well into every part of the equipment, remembering that its action is that of a dressing.

(*d*) After the leather has been allowed to become partially dry, it should be rubbed vigorously with a soft cloth to give it the neat, healthy appearance that is desired.

Oiling.—If the foregoing instructions have been carefully followed, the appearance should now be perfect, and if the leather is soft and pliable nothing further is required. It will be found, however, that it will be necessary from time to time to apply a little oil. It is not practicable, owing to different conditions of climate and service, to prescribe definitely the frequency of oiling. It has been found that during the first few months of use a set of new equipment should be given at least two applications of oil per month. Thereafter it is entirely a matter of judgment as indicated by the appearance and pliability of the leather. Frequent, light applications are of more value than infrequent heavy applications.

New Equipment.—Before using, perfectly new equipment should in all cases be given a light application of neat's-foot oil; soap is unnecessary because the leather is clean. The application of oil is important because leather equip-

ment frequently remains a considerable time in an arsenal or depot and in spite of periodical inspections and rubbing it is probably too dry for severe service.

How to Apply Oil.—The quantity of oil to be used cannot be definitely prescribed. If not enough oil is used, the leather will be stiff and brittle; if too much is used it will soil the clothing and accumulate dirt. The leather should, therefore, be saturated with sufficient oil to be soft and pliable without excess sufficient to cause it to exude.

In applying the oil the following general instructions should govern:

(*a*) The oil should be applied to the flesh side of the equipment where practicable when the leather is clean and still damp after washing (about half dry), because it penetrates more uniformly when applied from the flesh side, and when the leather is damp. If the leather is dry it will absorb the oil like blotting paper, preventing proper distribution.

(*b*) The oil should be applied with an oil rag or cotton waste by long, light, quick strokes—light strokes, so that the pressure applied may not squeeze out an excess of oil; quick strokes, so that the leather may not absorb an undue amount of oil. The endeavor should be to obtain a light, even distribution.

(*c*) After applying the oil the leather equipment should be allowed to stand for 24 hours, if practicable, in a warm, dry place. It should then be rubbed with a dry cloth to remove any unabsorbed oil.

Points to be Remembered.—Therefore, from what has been said, the following points must be remembered:

(*a*) Keep leather clean.

(*b*) Keep leather pliable by frequent applications of oil.

(*c*) Use only materials furnished by the Ordnance Department. *Shoe polishes*, etc., are almost invariably injurious.

(*d*) *Dry all leather wet from whatever cause, in the shade;* never in the sun or close to a steam radiator, furnace, or boiler.

(*e*) Leather should habitually be stored in a cool, dry place, *without artificial heat.*

MOTOR TRANSPORT CORPS.

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

ADMINISTRATION

LECTURE VI

RESPONSIBILITY.

CARE OF CLOTHING AND EQUIPMENT

General.—A soldier's clothing and equipment are issued to him by his Government for certain purposes, and he has, therefore, no right to be in any way careless or neglectful of them.

The importance that the Government attaches to the proper care and preservation of the soldier's clothing and equipment, is shown by the fact that the matter is made the subject of one of the Articles of War, the 84th, which prescribes that any soldier, who, through neglect, loses or spoils his arms, clothing or accoutrements shall suffer such punishment as a court-martial may direct.

Clothing.—Every article of clothing in your hands should receive as much care and attention as you give your person.

Not only will your clothes last longer if properly cared for, but you will look neater and better dressed, which will add much to your military appearance.

Pressing.—Occasional pressing helps to preserve and freshen clothes, it puts new life into the cloth. Woolen uniforms when worn regularly should be pressed about once a week. In a company where there is an iron for general use there is no reason why every soldier should not press his own clothes.

Chevrons can be cleaned by moistening a clean woolen rag with gasoline and rubbing the parts and then pressing with a hot iron.

Leggins.—When soiled, leggins must be washed. If the leggins are allowed to dry without being wrung out, they will look better.

The service hat and the overseas cap should be frequently brushed. If the service hat becomes out of shape, the brim should be pressed and the crown blocked if necessary.

Shoes.—Shoes should at all times be kept as clean as conditions permit. Russet shoes should also be kept well polished, and field and marching shoes well oiled. Neat's-foot oil is very good for the leather, increasing its pliability and life and helps to turn water.

Perspiration.—Shoes becoming damp from perspiration should be dried naturally by evaporation. It is dangerous to dry leather by artificial heat. Perspiration contains acid which is harmful to leather, and shoes should be dried out as frequently as possible.

Wet Shoes.—Wet or damp shoes should be dried with great care. When leather is subjected to heat, a chemical change takes place, although no change in appearance may be noted at the time. Leather when burnt becomes dry and parched and will soon crack through like pasteboard when strained. This applies to leather both in soles and uppers. When dried the leather should always be treated with dressing to restore its pliability. Many shoes are

burned while on the feet, without the knowledge of the wearer by being placed while wet on the rail of a stove or near a steam pipe. Care should be taken while shoes are being worn never to place the foot where there is danger of their being burned.

Mess Equipment

Knife.—The knife blade is made of tempered steel, and when put away for a long period should be covered with a light coating of oil to prevent rust. Keep your knife clean by washing in soap and water after every meal. Do not use the blade as a pry. If the point is broken, grind the blade down to a new point.

Fork.—Keep your fork clean by washing with hot water and soap after every meal. Never use the prongs of your fork for prying open tops of cans, extracting corks, etc.

Don't permit your knife, fork or spoon to remain in vinegar or other foodstuffs for a long period, as verdigris will form. This corrodes the metal and is poisonous.

Spoon.—Keep your spoon clean by washing with soap and water after every meal.

Meat Can.—Do not carry meat of any kind or other greasy substance in the meat can for a long period, as it will corrode the aluminum. If the rivets securing the hinges to the meat can become loose, a few blows with a hammer or hand ax on the outside ends of the rivets, the heads of the rivets being backed up on a piece of metal, will tighten them.

If the hinge pin becomes loose, a nail can be used to replace it, the nail being cut with a service wire cutter and the ends of the nail headed over slightly with a few blows of a hammer.

Bacon Can.—The interior of the bacon can should always be kept clean and free from hardened grease or dirt by frequent washings with soap and water.

If the cover becomes loose on the body of the can, the upper half of the body may be bent out until the cover is again tight.

If the cover is too tight, a slight amount of flattening with a hammer on the edge of the cover, resting on a wooden block, will usually extend the cover sufficiently.

Condiment Can.—When not in use, always remove the contents. Many cans have been ruined by neglecting to do this.

See that the threaded ends do not become rusty.

The can should be disassembled at all inspections, so that the inspecting officer may see that no rust is present.

Cup.—The cup is made of aluminum and excessive heat damages aluminum. In using the cup for cooking never allow the contents to evaporate entirely. In other words, never hold an empty cup over a fire.

Keep your cup clean with hot water and soap—preferably H. & H. soap.

Canteen.—Although as a rule, only soap and water should be used in cleaning aluminum, a little sand can be used to advantage in cleaning the canteen.

Particular attention must be taken to see that canteens are properly cleaned after they have been filled with coffee, milk or any other fluid containing organic matter.

Being made of aluminum the canteen is easily dented, and care must be taken to prevent this.

When not actually in use the canteen should habitually be emptied and the cup left off to dry.

Responsibility for M. T. C. Property

The term "responsibility" as used in this lecture implies a military and pecuniary obligation on the part of a person to control and preserve material entrusted to his care in such manner as to best serve the interests of the army. There will be a great many persons who will not be required to render accounts for motor vehicles entrusted to them, but the fact that such a person is not required to render an account or return of said properly in no sense relieves him of the responsibility, as above defined, which is automatically imposed upon him when any Government property comes under his care or control, nor of the obligation to maintain according to conditions of the service, a reasonable record or statement of his stewardship, or to furnish evidence, when properly called for, of the disposition which he has made of motor vehicles, parts, tools or accessories for which he is responsible.

The only way to insure satisfactory service from motor vehicles is to maintain them in the most scrupulous state of cleanliness, lubrication, and adjustment, and to devote timely attention to the condition of the tires, brakes, and minor repairs, in order to defer, as long as possible, the inevitable withdrawal of the vehicles from service for overhauling, and to prevent breakdowns on the road at a critical time.

Unnecessary damage to vehicles and excessive demands for spare parts, repairs and replacements are certain indications of unskillful use of equipment, just as large consumption of fuel and supplies, in proportion to the known transportation needs of a command, are taken to indicate waste and improper supervision and control.

In order to properly maintain the vehicles in serviceable condition, and to increase the number of days per year that they are in good operating condition, constant vigilance is necessary in detecting and reporting trouble and sending vehicles in ample time to service parks for repair or replacement of necessary parts. Vehicles should be sent to service and overhaul parks periodically, and should not be kept running until they break down or wear out, unless the exigencies of the service so demand.

General Principles of Care and Upkeep

Vehicle Maintenance.—(*a*) The general principles of good upkeep are the same for all motor vehicles. Certain routine operations *must* be periodically attended to by each driver. The necessary upkeep schedule to be followed is outlined below, and this procedure must be faithfully adhered to and constantly checked up by means of inspections. A copy of this Care and Upkeep outline should be a part of the equipment of each vehicle.

(*b*) Intelligent upkeep and repair demand a *thorough knowledge* of the particular type of vehicle operated by the company. For this reason each company will be supplied with a set of instruction books issued by the manufacturer. The company commander should fully realize that important minor repairs must often be made under trying circumstances, and by the drivers, unassisted by the company mechanics. This demands a knowledge of the car used, and the responsibility for adequate instruction of the men is upon the shoulders of the company commander.

(*c*) Much time ordinarily wasted by drivers waiting for their trucks to be loaded and unloaded, should be used to good advantage for lubrication, minor repairs, adjustments and general cleaning.

(*d*) Company commanders should most strongly impress upon their drivers the responsibility which the latter have for several thousand dollars' worth of equipment, and that this equipment at certain times may have a value which cannot be measured in dollars, owing to the urgent needs which may arise for its employment. In consequence, each driver should understand that his responsibility for his vehicle, is similar to that of a naval officer in charge of his vessel; that no matter what the circumstances are attending, damage to his vehicle or loss of equipment, a thorough investigation will be made, even though he is ultimately exonerated with honor. It should be made plain to him that excuses cannot be taken for ignorance of rules, failure to keep proper distance, to maintain proper speed, and to keep his vehicle absolutely under control at every moment that he is operating it. He is not only pecuniarily responsible for any damage which he allows to occur to the public property under his care, but he is also subject to disciplinary action for carelessness or negligence of duty in allowing this valuable property confided to him to be damaged. Ordinarily, no explanation is acceptable for damage to a vehicle, other than a collision by another vehicle, which the driver with all his skill and judgment could not avoid, or damage by hostile fire.

Rules.—The following rules are for the guidance of drivers, as well as for officers and non-commissioned officers. They represent the minimum of attention which must be given to vehicle maintenance, and will serve as a basis of inspection, and company commanders will see that they are carried out:

(*a*) Care must be given to *appearance*, as well as to mechanical perfection. See that the body and wheels are cleaned of dirt, and inside of body cleaned out.

(*b*) Be on the lookout at all times for all leaks, and for unusual noises; find the cause *immediately* and remedy it.

(*c*) In screwing up grease cups always make sure that the grease has actually been forced into the bearing.

(*d*) Never cut out the muffler.

(*e*) Never, under any circumstances, fill the gasoline tank or work on the carburetor in the presence of a naked flame or an oil lantern. If this work must be done in the dark, use an electric torch.

Log Book.—A log book is supplied for each vehicle. It must remain with the vehicle at all times, and the driver will be disciplined if it is lost. In it is entered a record of all repairs of any consequence made on the vehicle.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

ADMINISTRATION

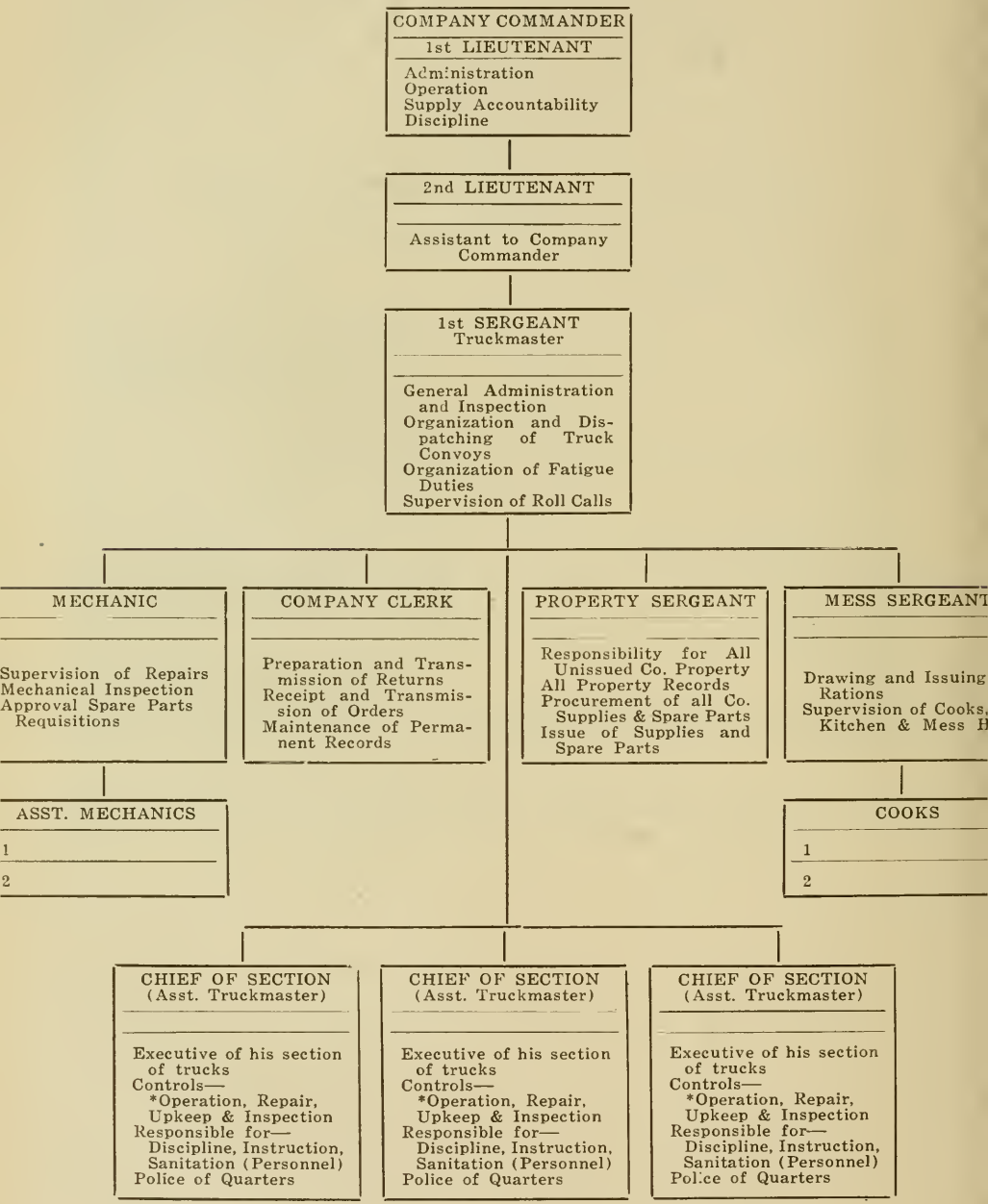
LECTURE VII

ORGANIZATION OF MOTOR TRANSPORT COMPANY

The organization of a Motor Transport Company is as follows:

PERSONNEL AND EQUIPMENT		REMARKS
1st Lieutenant	1	a. Truckmaster.
2nd Lieutenant	1	b. 1 Clerk; 3 Chiefs of Sections (assistant truckmasters); 1 Mess Sergeant; 1 Property Sergeant; and 1 Mechanic.
Total commissioned	2	
1st Sergeant	a1p	c. 2 Assistant Mechanics and 32 Drivers.
Sergeants	b7-1p6r	d. 9 Assistant Drivers and 1 Messenger.
Corporals	cr34	e. Assistant Driver.
Cooks	2r	p. Armed with Pistol.
Privates, 1st Cl.	dr10	r. Armed with Rifle.
Privates	er24	v. Class A or Class B.
Total Enlisted	78	w. 1 Truck, Light Repair and Truck for Company Supplies (Class AA).
Aggregate	80	
Cars, Motor, Light		
Open (5 Pass.)	1	NOTE: If company is partially or fully equipped with passenger cars instead of truck substitute two passenger cars for each cargo truck of Class A or Class B.
Motorcycle with side car	1	
Trucks, cargo	v27	
Trucks, cargo	w2	
Kitchens, rolling		
Trailmobile	1	NOTE: Class AA is three-quarter ton truck.
Trucks, tank	2	Class A is one and one-half ton truck.
Pistols	4	Class B is three-ton or over truck.
Rifles	76	

The following chart shows in graphic form the division of duties and responsibilities in the company.



*Includes Responsibility for Drawing Gasoline, Oil and Grease.

The motor transport company is normally organized into three sections of nine trucks, each section under command of an assistant truckmaster. The service trucks, i. e., tank trucks, etc., are usually kept under the immediate order of the truckmaster, as they do not form an integral part of the cargo sections. When the company is not operating in convoy, the service trucks may be assigned to cargo work, and in such cases should be attached to sections.

Duties and Responsibilities

(*a*) First Sergeant: He is the truckmaster and the executive of the company. He sees that all orders, regulations, and other requirements are properly carried out that the men perform their duties properly; and reports to the company commander any cases of neglect or violation of orders requiring disciplinary action. He should be a man chosen more for his administrative and executive ability and his efficiency in handling men than for his mechanical knowledge. The mechanic may well be chosen for his ability as a mechanic, irrespective of his ability to handle men, but the first sergeant should be a man of force, as his prime duty is to maintain discipline for the efficient operation of the company.

(*b*) Mechanic and Assistant Mechanics: The mechanic and assistants are under the direct control of the first sergeant. The mechanic should be held responsible that the necessary repairs are made to the mechanical equipment of the company. He is in charge of the repair truck, and tools and equipment pertaining thereto. He should sign for the tool equipment and issue it to the assistant mechanics on proper receipts. He should be held responsible that this equipment is properly maintained and that any shortages by damage, loss, etc., are properly made up. Normally, he should see that the assistant mechanics are qualified, and should instruct them in their work. In order to perform their duties properly, the mechanic and assistant mechanics should be thoroughly familiar with the instruction books issued by the maker of the vehicles furnished to the company.

(*c*) Company Clerk: He has charge of all records, reports and correspondence of the company. As he is habitually called upon to notify members of the company as to orders and instructions received, or to call upon them for the rendering of prescribed reports, and in consideration of other incidents where he must exercise authority, he has the rank of sergeant. Other duties for him are prescribed by the company commander according to local conditions.

(*d*) Property Sergeant: He is responsible for all supplies and equipment not actually issued to individuals, and will keep the necessary records therefor. He is responsible, moreover, that all issues of property are receipted for by the persons responsible. He keeps the property under his charge clean and in good order, and should have a list up to date of all property and its disposition. All dealings with the quartermaster or supply officer, not requiring the personal intervention of the company commander, should be carried on by him.

(*e*) Mess Sergeant: He has direct charge of the mess hall, kitchen and all matters pertaining thereto, including supervision of the cooks or other men working in the kitchen. He draws the rations, sees that they are economically used, makes up bills of fare, sees that the kitchen, mess hall and premises are clean and sanitary, and that all orders in reference thereto are carried out. His authority to contract debts, or expend money should be carefully watched and checked by the company commander personally. In some cases the duties

of mess sergeant are performed by the property sergeant, but this depends on the special aptitude of the man, as well as on other local conditions in the company.

(*f*) Chiefs of Sections: Each chief of section (assistant truckmaster) is responsible for the discipline, instruction and all other matters pertaining to the personnel of his section; for the operation, repair and upkeep of the equipment assigned thereto. He is the intermediary between the men of his section and the truckmaster or company commander. His supervision extends to all the details connected with his section, including police and sanitation of quarters, seeing that his men are provided with the necessary equipment and clothing. All orders for his section, either to the various members of his personnel or to the units of his equipment, should be given to him. He should assure himself that his section is in proper condition at all times by making regular and systematic inspection of his men and equipment. He should examine all his vehicles on their return from work, and see that the drivers have taken care of them and that the proper repairs are made. In his absence, for any cause, a suitable man should be designated to perform his duties.

(*g*) Driver: He keeps his vehicle and its equipment clean and in good repair and working order. In order to do this, he utilizes his spare time while not on duty to do the minor work required thereon. He should be especially required to attend to the proper lubrication of all parts and truck mechanism, and to report promptly any defect noted or repair needed. In transporting material or supplies, he will see that the vehicle is not overloaded, that the cargo is properly loaded and lashed, and ordinarily he is responsible for its safe delivery. He should be familiar with the mechanism of his vehicle and its proper operation, and for this purpose he should be thoroughly familiar with the contents of the instruction book issued by the makers of the vehicle. He should be required to wear proper uniform when driving.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

ADMINISTRATION

LECTURE VIII

STOLEN PROPERTY AND ACCIDENT REPORTS

(*a*) Instructions to Chauffeur. M. T. C. N. 140a-b.
(*b*) Stolen property report. M. T. C. No. 111.
(*c*) Drivers' Accident Report. M. T. C. No. 124.

Note: The three forms covered in this lecture are to be introduced into class, carefully looked over and discussed.

Instructions to Drivers of Automobiles and Motorcycles

M. T. C. Form No. 140a-b

These cards are self explanatory. Each driver should be supplied with a copy of these instructions, and it is his duty to faithfully comply with these instructions.

Stolen Property Report

M. T. C. Form No. 111

The purpose of this report is: (*a*) to furnish information to the nearest Assistant Provost Marshal in case of stolen property, to aid in its recovery.

(*b*) To inform the Office of the Director, Motor Transport Corps, of the loss of M. T. C. equipment, in order that they may take steps to provide for necessary replacement, and in order to insure necessary corrections in the files of Registration and Organization cards.

(*c*) This report is used by all officers or other persons responsible for motor vehicles or equipment of same in cases where this property is stolen.

(*d*) Four copies of this report will be made out and disposed of as follows:
1. The original copy will be forwarded to the Director, Motor Transport Corps.

2. The second copy will be forwarded to the Motor Transport Officer of the Section in which the vehicle is operating, or, in case the property stolen was assigned to a Division, Corps, Army, Corps Troops or Army Troops, to the Motor Transport Officer of the unit to which the vehicle was assigned when stolen. All officers receiving this report will take such measures as may be possible under the circumstances, to aid in the recovery of the stolen property.

3. The third copy will be turned over immediately to the Assistant Provost Marshal whose headquarters are located in the territory where the property was stolen.

4. The fourth copy will be retained by the officer or other person making out the report.

(*e*) This report will be filled out properly, giving as much detail as possible, and delivered in person or mailed as "URGENT OFFICIAL MAIL."

Drivers' Accident Report

M. T. C. Form No. 124

This form is used to serve as instructions for drivers as to their procedure in case of injury, however slight, caused by their vehicles to persons, animals or property; and to serve as the written report of the accident.

The form is filled out by the driver immediately after the accident, and delivered to the commanding officer of his organization, who will certify on the form the date and hour of receiving the report.

The importance of making out this report promptly is emphasized by the fact that commanding officers are directed to institute court-martial proceedings against drivers who fail to render such report immediately upon return to organization.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

ADMINISTRATION

LECTURE IX

M. T. C. PAPER WORK

A. G. O. 29	Service Record.
M. T. C. 130	Personnel Report for Enlisted Men.
A. G. O. 637	Individual Equipment Record.
Q. M. C. 41	Soldier's Deposit Book.
	Log Book.
M. T. C. 117	Daily Receipts and Issues of Gasoline, Lubricants, etc.
M. T. C. 120a-b	Commutation of Rations and Lodgings for Drivers.
M. T. C. 124	Driver's Accident Report.
M. T. C. 111	Stolen Property Report.
Q. M. C. 509	Delinquency Record.
A. G. O. 594	Records of Court-Martial.
A. G. O. 525	Honorable Discharge.
Q. M. C. 370	Final Statement.

The following is a brief description of the most important forms, from the standpoint of the driver, used in the administration of a motor transport company.

Service Record, (*Form A. G. O.* 29).—When a soldier is enlisted or re-enlisted, a service record on this form is opened for him by the recruiting officer, who fills out the descriptive list, Prior Service, and the first part of the current enlistment. All other data called for will be filled from time to time by the soldier's company or detachment commander, and must be entered promptly and accurately. Each entry made under Military Record, Allotments, and Clothing Account, must be initialed by the officer making the entry. When a soldier is transferred or detached from his company, the company commander will fill out the proper indorsement and forward the Service Record to the soldier's new commanding officer. A copy of each indorsement will be kept by each officer forwarding a Service Record. Each indorsement will give the authority for the change of station or status of the soldier, his character, and a full statement of his accounts at the time.

M. T. C. Personnel Report for Enlisted Men, (*M. T. C. Form* 130).—This report is to be used only in case of enlisted men in the M. T. C., and is to be forwarded to the Director, M. T. C. It shows the man's qualifications and experience.

Clothing Record—Individual Equipment Record, (*A. G. O. Form* 637).—One of these forms is made out for each man in the company and contains an exact list of his equipment both of quartermaster property and ordnance property. The soldier places his initials at the bottom of the column where items are charged to him, as does the commander of his company. This is done each time articles are issued to the soldier (not in exchange for worn out articles), and each time the soldier turns in articles an entry to that effect is made on the form, initialed in the same way.

The form itself is attached to the soldier's service record and becomes a part of it. The soldier is thereafter responsible for every item charged against him and must be able to produce them on demand. If he loses or injures them through neglect, he must pay for them.

Soldier's Deposit Book, (*Form Q. M. C.* 41).—Any soldier may deposit with the quartermaster a sum not less than five dollars at any one time to bear interest at the rate of four per cent per annum on all sums on deposit for six months or more. A soldier's deposit book will be furnished to every soldier making such deposits, such deposits to be receipted for by the Quartermaster and attested to by the company commander. The book is kept by the soldier and must be presented with his Final Statement for payment. It cannot be assigned or transferred, nor can the soldier withdraw the money until he is separated from the service.

Log Book.—A log book is issued for each motor vehicle in the A. E. F. which bears the same relation to the vehicles that the service record does to the enlisted man. This book must at all times remain with the vehicle, and it is of utmost importance that all data required be entered promptly and accurately by a responsible person. It shows transfers of the vehicle and spare parts provided or repairs made on it. A durable envelope is furnished with every log book, and it has a definite place on the vehicle. Care must be used in handling this book to keep it as clean as possible.

Daily Receipts and Issues of Gasoline, Lubricants, etc., (*Form M. T. C.* 117). —This is a daily record of gasoline and supplies received and issued by a company. It is to be kept by the supply sergeant and turned in to the organization office at the end of the day, the information consolidated on M. T. C. Form No. 118. The driver must sign for these items on this form whenever he receives them either in his own company or from some refilling station.

Commutation of Rations and Lodging for Drivers, (*Form M. T. C.* 120a-b). —Form 120a is to be used as a voucher for the payment of commutation of rations and lodgings for soldiers traveling under special orders, specifically directing the soldier's travel either with or without officers. Upon completion of the trip it will be certified to by an officer, in accordance with printed directions on the inside of the cover. The original and one carbon copy are to be given to the soldier for presentation to the disbursing officer in order that the soldier may be paid the commutation due him. The third copy is forwarded to the commanding officer of the organization to which the soldier is assigned for rations.

Form M. T. C. 120b is used for commutation of rations and lodging for a soldier traveling as driver to an officer, in case the travel performed by the soldier is not specifically covered by the order directing the travel of the officer or the vehicle. This form is to be filled out and certified to as per directions printed on the inside of the cover. The disposition of the copies is the same as for form 120a. It is important for the driver to be sure and get these forms made out at once, as otherwise the officer whom he has driven may not be available to sign them and the driver will therefore never be able to collect this commutation.

Driver's Accident Report, (*Form M. T. C.* 124).—This form is used to serve as instructions for drivers as to their procedure in case of injury, however slight, caused by their vehicles to persons, animals or property, and to serve as their written report of the accident. The form is filled out by the driver immediately after any accident, which results in injury to persons or property. It is then delivered to the commanding officer of his organization, who will certify on the form the day and hour of receiving the report. Failure to make

out this report immediately will result in disciplinary action being taken against the driver.

Stolen Property Report, (Form M. T. C. 111).—This report will be made out in case of any article of M. T. C. property which has been stolen. Four copies will be made, the disposition being as follows: original and second copy forwarded to H. Q., M. T. C., the third copy to be turned over immediately to the Assistant Provost Marshal of the territory in which the property was stolen, the fourth copy to be retained as a record for the company. This record must be filled out and mailed promptly.

Delinquency Record, Enlisted Men, (Form Q. M. C. 509).—In the office of the company is kept a loose leaf file of this form with the name of each man on a separate sheet. Whenever the man commits an infraction of the rules, that fact is entered on the sheet together with the penalty inflicted. The purpose of it is twofold—first, to determine the punishment to be inflicted; thus, a man who is a frequent offender will get a more severe punishment than a first offender; second, to be able to determine at a glance the character of the man for purposes of promotion or indorsement on service record in case of transfer. It therefore behooves every man to see to it that his delinquency record remains free from entries, for his own advancement depends entirely upon it, and every offense he commits is noted and remains a permanent blot on his record.

Records of Court-Martial, (Form A. G. O. 594).—A copy of all charges preferred against men in the organization, Form A. G. O. 594, must be kept as a permanent record. It is prepared in triplicate, one copy is retained in the office appointing the summary court, one copy forwarded to the Adjutant General, and the third copy returned to the company. It includes a statement of charges preferred, with a record of the disposition of the case by the court-martial, and is attached to the service record of the man.

Honorable Discharge, (Form A. G. O. 525).—An honorable discharge is given to every soldier discharged from the Army when his conduct has been such as to warrant accepting him for re-enlistment, and his service has been honest and faithful.

Final Statement, (Form Q. M. C. 370).—The final statement is a statement of his account with the United States given every enlisted man on his discharge or furlough to the regular army reserve, and is the voucher on which he is paid. It is made out in duplicate and both copies must be presented for payment. It contains a statement of clothing account, pay, deposits, etc. The soldier's immediate commanding officer will have the statement prepared and will certify to its correctness. No final statement is given in case there is nothing due the soldier, but a letter to that effect is given him. The soldier takes the final statement to the Quartermaster for settlement. He may, if he desires, assign or sell it to some other individual, but this has to be done in a certain way, otherwise the assignment is invalid. The easiest way for the soldier to have his accounts settled is to take them directly to the Quartermaster.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

ADMINISTRATION

TYPICAL QUIZ QUESTIONS (FOLLOWING FINAL LECTURE)

1. What are the four types of cartridges?
2. What is powder-fouling?
3. What is metal-fouling?
4. What means are taken to keep arms in perfect shape?
5. What two agents are necessary for the proper cleaning of leather?
6. Give three rules for cleaning leather.
7. Give two rules for oiling leather.
8. What is meant by responsibility?
9. Give three rules for the proper maintenance of motor vehicles that should be followed by drivers.
10. What is a log book?
11. What are the duties of the first sergeant,
12. What are the duties of mechanic and assistant mechanics?
13. What are the duties of the property sergeant?
14. What are the duties of the chiefs of sections?
15. What are the duties of drivers?

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

ADMINISTRATION

TYPICAL WRITTEN EXAMINATION QUESTIONS

1. Give the rules for the proper hand salute.
2. Name the five qualifications upon which ability is determined in the army.
3. What is meant by the brief of a letter?
4. Give the channels through which a letter from an enlisted man requesting a furlough would pass, assume that the enlisted man is a member of a motor transport company which is a part of a motor command in a camp in this country.
5. Write a military letter requesting a furlough; add one indorsement.
6. Give the rules that should be observed in the handling of secret communications.
7. Give the rules that should be observed in the handling of confidential communications.
8. Under what circumstances may a private individual use a penalty envelope?
9. Give the kinds of courts-martial and the number of men comprising each.
10. What are the powers of a general court-martial?
11. What does Army Regulations cover?
12. When does a decision of a court-martial go into effect?
13. What is a countersign; a parole?
14. Give five rules to be followed by a sentinel guarding prisoners.
15. Write a short treatise on the care of arms and equipment.
16. Give five rules for the care of clothing.
17. Outline the duties and responsibilities of the noncommissioned staff of a motor transport company.
18. What is the stolen property report Form M. T. C. 111; when is it used and what disposition is made of the various copies?
19. Tell all you know about the driver's accident report Form M. T. C. 124.
20. What data is given in A. G. O. Form 637 individual equipment record?
21. Tell all you know about Form M. T. C. 120a and 120b, commutations of rations and lodgings for drivers.
22. What is a delinquency record Form Q. M. C. 509?
23. What is a record of court-martial A. G. O. 594?
24. Under what circumstances is an honorable discharge given?
25. What is a final statement Q. M. C. Form 370?

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

MILITARY INSTRUCTION

The material covered by the following references will be given by brief lectures on the drill field, in the barracks on rainy days, in evenings, or at such other times and places as the instructor shall feel advisable and necessary. It is not felt to be necessary to group these references to cover special hours of the course, as the amount to be covered, as well as the proper time in the course when it should be taught, must be left to the judgment of the instructor.

References:

1. Manual for Non-Commissioned Officers and Privates of Infantry, Paragraphs 48 to 73, inclusive.—School of the Soldier.

   Men should memorize "Position of the Soldier."
2. Manual for Non-Commissioned Officers and Privates of Infantry, pages 9 to 18, inclusive.

   Instructor should give a talk on Military Discipline and Courtesy.
3. Manual for Non-Commissioned Officers and Privates of Infantry, paragraphs 71 and 72.

   Soldier should memorize marching to the rear and marching by the flank.
4. Manual for Non-Commissioned Officers and Privates of Infantry, paragraphs 77 to 94, and 98 to 100.
5. Small Arms Firing Manual.
   Chapters 1 and 2.
   Position, Aiming and Trigger Squeeze Exercises.
6. Manual for Non-Commissioned Officers and Privates of Infantry, paragraphs 98 to 100, page 74.
   Paragraph 745, page 111, first section.
7. Manual for Non-Commissioned Officers and Privates of Infantry, paragraphs 101 to 122, inclusive.

   Men should memorize Squad Right and Squad Right About.
8. Articles of War:

   Articles 1, 2, 29, 54 and 96, inclusive, and 104 to 109, inclusive, shall be read and explained.
9. Rules of Land Warfare.
   Chapter 4, paragraphs 45, 46, 49 to 53, inclusive, and 57 to 60, inclusive.

NOTE.—In all cases where it is necessary for the men to memorize any positions of marches, etc., mimeographed sheets of the material shall be supplied to them.

Motor Truck Company Drivers' Course

LABORATORY

LECTURE 1

TIMING GEARS AND VALVES

If two gears, running together, or in other words in mesh, have the same number of teeth, they may make the same number of revolutions. If the driven gear has twice as many teeth as the drive gear, it revolves once while the drive gear is revolving twice. This is called a two to one or half-time gear. Since the cam shaft must revolve only once to every two revolutions of the crankshaft, the cam shaft gear has twice as many teeth as the crank shaft gear. The cam shaft revolves in the opposite direction from the crank shaft when driven by gears without an idler, and in the same direction when driven by a chain.

The wide face helical gear is most popular for the timing gears. Special material as fabroil, micarta and other compressed materials are used by many manufacturers for making gears which are silent. Drop-forged gears are also used to a great extent; also steel for the crank shaft gears and cast iron for the cam gear.

The silent chain for driving the generator is quite popular. It is also being used to a certain extent for driving the cam shaft. The object is to obtain quieter running. This type of chain must not be confused with the ordinary roller type as used on chain-driven trucks. The silent chain is more positive in action, otherwise the timing would be thrown out of adjustment. The teeth on a sprocket used for a silent chain are very close together and accurate. Any undue slack in the chain can be taken up by sliding the magneto or generator shaft outward. This chain is self-adjusting for pitch, as there is an allowance of twenty-thousandths (.020) clearance before chain bottoms in sprockets.

Purpose of Valves

There are two valves to each cylinder, to all four-cycle gasoline engines; an inlet valve and an exhaust valve. There are three types in general use; the poppet, sleeve and rotary, the poppet type being used almost exclusively.

The inlet valve admits fresh gas to the cylinder. Fresh gas is going into the cylinder during only one stroke of ever four, or in other words, during one stroke of every two revolutions of the crank shaft.

The exhaust valve permits the burned gases to escape. It is opened and held open by a cam on the cam shaft. This is called being mechanically operated. Mechanically operated valves are opened and held open by means of cams which work against a strong spring tension. The exhaust valve is always mechanically operated, except in some of the old types of motorcycle engines in which the inlet valves were automatically operated.

An automatically operated valve is held against its seat by a light spring. During the suction stroke the sucking action of the piston, as it slides downward in the cylinder, draws the valve open. At the end of the suction stroke, when the suction ceases, the spring pushes the valve disc back to its seat and

the gas is prevented from escaping past the valve. It must be understood that the valves of a gasoline engine always open inward. Thus the pressure from the power and compression strokes tends to keep the valves firmly on their seats.

Usually inlet and exhaust valves are made the same size. Some manufacturers are making the inlet larger. For instance, the Sterline engine has 1¼-inch intake valves and 1⅛-inch exhaust valves. The lift of a valve is the height it is raised from its seat by the cam. Side operated valves may be placed all on one side, or on opposite sides of the cylinders. When on opposite sides two cam shafts are necessary, one on each side. When all valves are on one side, one cam shaft is sufficient.

To grind valves, in an overhead valve engine with detachable head, the head is removed with the valves, and the valves are ground in the head. In an overhead valve engine with cage-type valves the valves are ground in the cage. To grind valves on a side valve engine, the valve caps are removed if the head is integral with the cylinder. If the head is detachable, then the head is removed and the valves are ground in their seats in the cylinder pockets.

Although the valves vary in location and methods of operation, the principle remains the same; the inlet admits fresh gas; the exhaust valve opens at the correct time to allow the burned and used gas to escape.

A valve has three parts; a head and a stem which forms the moving part, and a valve seat, on which the valve fits. When closed, the valve head must fit in its seat so that it is absolutely tight. When open there must be sufficient space to let the gas pass freely.

The valve spring holds the valve tight on its seat and must have tension at all times. If the spring is too strong the valve closes with undue noise. If too loose, the valve does not seat properly. The exhaust valve spring usually weakens first on account of the intense heat to which it is subjected.

The valve spring washer is placed at the bottom of the spring and is held in place by a key or retainer under tension of the spring.

Before the student can understand the subject of valve timing he must first learn the four-cycle principle, as it is entirely with this principle we will deal. In addition, the meaning of degrees, and the relation of the valve cam speed to the engine crank-shaft speed, and the importance of valve clearance adjustment, must be thoroughly understood.

If no space were left between the end of the valve stem and the cam, even very slight wear on the valve tappet seat would prevent the valve from closing properly. As the stem expands, it gets longer, so that if no clearance were provided, the stem when pressed would rest against the tappet and the valve would not seat properly. Valve clearance, also called air gap space, is the space between the end of the valve stem and the tappet. The width of this space ranges from the thickness of tissue paper to 1/16 of an inch. The average gap is somewhere about or slightly less than a postal card thickness. Some manufacturers give about 1/1000 of an inch less to the inlet than to the exhaust, because the exhaust valve stem lengthens slighly when heated. For instance, the Hudson gives .004 of an inch to the air gap space on the inlet valve and .006 to the exhaust. The adjustment should always be made when the engine is cold and after the valves are ground, as the grinding will slightly lower the valve.

The inlet cam has a sharp nose. The exhaust cam has a broader nose, because it must hold the valve open longer. The width of the nose, less the gap, regulates the lift. The average lift of either exhaust or intake is approxi-

mately ⅜ to 9/32 of an inch. It is thus evident that if the air gap is ⅜ to 9/32 of an inch too large, the valve will not open at all. If such an air gap (⅜ inch) is slightly decreased, the valve will lift very slightly and stay open but a few degrees of the revolution. If the air gap is again slightly decreased the valve opens sooner, raises higher and closes later. This process can be repeated until there is no air gap left. Now, suppose an engine is designed to have 1/16-inch air gap, and there is no air gap at all; the valves will open possibly 30 degrees too soon, raise 1/16-inch higher than intended and close 50 degrees too late.

As to the wear of the end of the valve stem or toppet, it is apparent that as the wear increases the space or air gap increases and the valves have less lift, open later, close earlier, and become noisier, all of which affect the power of the engine. When valves are noisy, the cause is usually traceable to the wear of the valve stem, although they are all case-hardened at the end as well as the head. The wear, however, comes with time. Too great a lift also causes noise.

Always adjust the valve clearance to the measurement given by the manufacturer. It is important that the valve clearance adjustment be made with the back lash or lost motion in the driving gear entirely taken up in the direction of rotation.

If one of the cams raises an inlet valve just as the piston is starting down on the suction stroke, then a charge of gas is drawn into the cylinder as long as the piston is on the suction stroke and the valve is open. Therefore, the valve should open in time to give the piston a chance to draw in a cylinder full of gas. If the valve opens after the piston starts its suction stroke, then it does not get a full cylinder of gas, and thereby gives less power. Therefore, it is important that the inlet valve be made to open at the right time. The method employed to cause it to open at the right time is by means of the inlet valve timing gear and proper valve clearance. The practice is to allow the piston to descend slightly in the cylinder on the suction stroke before the inlet valve opens, so as to reduce the pressure and to create, if anything, a suction.

In regard to the closing of the inlet valve, it is almost universal practice to let the valve stay open uptil the piston has not only reached the bottom of dead center, that is, the bottom of the stroke, but has actually traveled slightly up on the compression stroke again. The gas sucked in thus would be forced out again if it were not for the great piston speed. For instance, there are 15 complete cycles of operation in one second, or one stroke on the piston to one-sixtieth part of a second. This is such a speed that the piston has reached the bottom of its stroke in an appreciable time before the gas has been able to fill the cylinder. Therefore, after the piston has started to move upward on the compression stroke, there still remains suction in the cylinder, which, if the valve remains open, continues for a short interval to draw in a further charge of gas.

Obviously the exact point at which the inlet valve should close depends upon the speed of the engine; and whatever setting is arranged will not be equally suitable for all speeds attained by the engine. As for instance, when the engine runs dead slow, the late closing is a distinct disadvantage. The gas is then drawn back on the compression stroke, while at maximum speeds the valve closes before the suction has completed its work. There is, however, an average speed for the engine—in fact, for every engine—and the valves are set to the average speed.

Exhaust Valves Opening and Closing

There are two opinions about the opening of an exhaust valve. The valve must open considerably before the piston reaches the end of the explosion

stroke; and if this wastes some of the force of the explosion, this waste may be amply compensated for by the freedom afforded the piston in commencing the exhaust stroke.

It is obviously wrong to keep the exhaust valve closed up to the very moment before the piston is about to move upward, because on commencing the exhaust stroke it finds itself confronted for an instant with the force which has just pushed it down. Until the valve is wide open, it is considerably impeded in its journey upward.

For this reason, the exhaust valve is usually opened as soon as the piston has moved through about seven-eighths of the power stroke; that is, before the bottom of dead center is reached. The exhaust valves if opened too early cause a waste of power. Stationary gasoline engines, which run at lower speeds than automobile engines, do not hold their valves open so long, the chief difference being in the interval of exhaust opening and inlet closing.

There is little to be said as to when the exhaust valve should close. It may close before the end of the stroke (exhaust stroke). As a rule, on account of what has been explained about the gas which remains in the head of the cylinder being slightly under pressure at the end of the stroke, the valve is quite often allowed to remain open until the piston has moved slightly down on the suction stroke. This gives full opportunity for as much exhaust gas to escape as possible.

In order to understand just how important it really is to expel all of the burned or exhaust gases, it must be explained that one of the chief components is carbon dioxide, which is the most powerful anti-combustion agent known to science. Its presence, therefore, even in small quantities, retards considerably the speed of the explosion development.

The piston now having come to rest at the top of the stroke, there is still the problem of dealing with the burned gases which remain; and for the throwing off of these we must take advantage of the exhaust momentum.

The manner in which this principle operates will be apparent if the contents of the exhaust pipe are pictured as a mass of gas moving outward at piston speed. When the influence which started this movement has stopped, namely, at the top center, the gaseous mass moves almost like the piston of an air extractor pump; and if the valve timing permits, it tends to draw out with it from the cylinder a large proportion of the remaining gases.

If the extractor action of the exhaust gases is to be taken advantage of, the valve must be made to close a little later than the top center, or, as it is technically explained, must have a certain degree of lag. It is evident that if we close it at the exact top of the stroke, the contents of the combustion chamber are imprisoned and contaminate the incoming charge.

The amount of this lag depends on the shape of the combustion chamber, the weight of the valves, the strength of the springs and the design of the exhaust system.

Valve Timing and Firing Order

The difference in size of the bore and stroke of the cylinder, particularly in the stroke, the type of ignition, the shape of the manifold and the speed of the engine, governs the valve timing. Early setting of valves on an engine causes irregular firing at lower speeds, unless a very heavy flywheel is used. It also increases the gasoline consumption in short stroke engines.

For high speed work, the inlet may be opened and closed late. For low speed work, closing the inlet and exhaust on the center gives the best control

and eliminates blowing back. The moment of opening and closing the valves with reference to the engine speed, of course, has an important bearing on its performance. If the valves open too early, back firing results, while if they open too late, a sluggish engine and overheating result.

In actual practice the inlet valve seldom opens on the exact top of the stroke but usually after the top of the stroke, varying from 5 to 15 degrees. The inlet seldom closes when the piston reaches the bottom, but from 5 to 38 degrees after bottom. The exhaust valve seldom closes on top of the stroke, but usually 5 to 10 degrees after the top. The position of the crank shaft determines the position of the piston. The position of the piston determines the point where the valve is set to open or close. Therefore, the cam shaft must be set so that the cam raises the valve when piston is at a certain point. This is accomplished by meshing the cam gear with the crank shaft gear when the piston is in the correct position. Marks are usually placed by the manufacturer on the cam gears which indicate just where to mesh the gears. The flywheel is also sometimes used for timing.

Setting of Valves, Multiple Cylinder Engine

There must be at least one inlet and exhaust valve for each cylinder. Therefore there must be four cams for the four inlet valves and four cams for the four exhaust valves.

If the cylinders are "T" head, there are two cam shafts. If they are "L" or over-head there is only one cam shaft.

It is well to note that in four, six, eight or twelve cylinder motors, each piston passes through the four strokes during two revolutions of the crank shaft.

The usual plan is to place the piston of cylinder No. 1 at the top of its stroke and to work from that point in timing valves. The cams do not need to be set on the shaft, but when the cam gear in front of the engine is meshed with the driving gear, the position of the nose of the cams can be adjusted.

The usual plan to time the valves or set them in correct time with the cam shaft is to mesh the cam gears so that the points marked on them will correspond with the marks on the crank shaft gear, at the time No. 1 piston is on top of its stroke. Usually marks also appear on the circumference of the flywheel that indicate the position in which the crank shaft is to be placed for the correct setting of the valves. The mark of the flywheel is placed in line with a center mark on the cylinder or elsewhere. If there are no marks on the gears or the flywheel, then it is necessary first to determine where to set the valves.

There are four strokes to two revolutions of the crank shaft to complete a cycle operation, as explained previously.

A stroke of a piston means to travel from top to bottom or bottom to top, or 180 degrees movement; one-half a revolution of the crank shaft.

There is but one power stroke during the four strokes, or two revolutions of the crank shaft. Also, note that the power stroke is a very short one; owing to the fact that the exhaust valve starts to open considerably before the piston reaches the bottom of its stroke. As the exhaust valve opens 46 degrees before bottom, the travel on the power stroke, that is, the stroke actually under full pressure, is 134 degrees instead of 180 degrees. Therefore, since there is but one power stroke to two revolutions of the crank shaft, in only 134 degrees out of the two revolutions (720 degrees travel of the crank shaft) would there be power. One full revolution of the crank shaft

being 360 degrees, there are 720 degrees in two full revolutions; but only 134 degrees are actually under pressure as explained.

In an engine with one cylinder, there is an explosion once during every two revolutions of the crank shaft. In other words, there is one stroke of the piston when the power is being developed, and three when there is no power, the piston being then moved by the momentum of the flywheel. As the piston must be carried through the three dead strokes, it is necessary to use a heavy flywheel, so that when the flywheel is started it will continue to revolve for a sufficient time to move the piston until the next power stroke. There is vibration from a one-cylinder engine on this account, as the weight of the piston sliding first one way and then the other has nothing to balance it. The more cylinders an engine has, the more steadily it will run, because the explosions may be arranged to follow one another so closely that there is no moment when one of the pistons is not on the power stroke.

Cooling System

If no provision is made for the cooling of the cylinder of a gasoline engine, the intense heat of the explosions will heat it to a point that will cause the lubricating oil to burn and become useless. At the same time, the cylinders must not be kept too cool, for that prevents the development of full power.

The cylinder must be permitted to get as hot as is possible without burning the lubricating oil. Between 170 and 200 degrees Fahrenheit, or just below the boiling point, appears to give the best results.

The cylinder may be cooled either by water or by air, and while the greater number of engines are water cooled, air cooling has been developed to a point where successful results are attained. As trucks are practically all water cooled, we consider only the water cooling system.

The water cooling system consists of water jackets around the cylinder that is to be cooled, and through these jackets water may flow; a radiator for cooling the heated water; and some method of keeping the water in circulation, together with the necessary connections.

The jackets are usually cast in one piece with the cylinder, although in some cases they were formerly sheet copper pressed around the cylinder to form passages through which the water would circulate. When heated, the water passes to the radiator, where the rush of air to which the radiator is exposed absorbs the heat and cools the water.

To maintain the cylinders at a workable temperature, a quantity of water is carried in a supply tank or radiator from which the water is caused to circulate continuously through the jacket of the engine cylinder by a small pump driven direct from one of the cam shafts, or by the thermo-syphon principle. The heated water from the cylinder returns to the tank or radiator and there passes through a series of thin copper tubes, the object being to dissipate, as much as possible, the heat absorbed by this water, by exposing the water to a large cooling surface of metal.

The cooling system is almost always fixed in the forward part of the car, to obtain the full benefit of the draught of air. The same water is used over and over again, so that it is necessary only to replenish the loss caused by evaporation.

It is usual with cooling systems to have a rotary fan to assist in pulling a draught of cold air through the radiator and in accelerating the cooling when the car is running slowly, as in hill climbing, or slow movement of traffic. The fan is driven from the engine shaft by a belt or gear and is at the back

of the radiator. The alternative method, which avoids the use of a separate fan, is provided by using the flywheel as a fan.

The two systems of circulation are the thermo-syphon and the force or pump feed system.

Thermo-Syphon System

The Thermo-syphon circulation system has for its principle the fact that when water is heated, it rises. The connections are the same as for the force or pump feed system, except that there is no pump, and the connection from the water jacket outlet to the top of the radiator slants upward. It is more necessary to have clear passages for the thermo-system than for the force system, because the pump, in the force system, forces the water past an obstruction that would stop the flow of water which moves only because of its heat.

Height of Radiators, Thermo-syphon System

In this system the radiator must be higher and lower than the extreme top and bottom of the water jackets.

Height of Water

Thermo-syphon System: To circulate properly, water must be kept above the level of the top opening of the radiator from the engine. Below this point circulation ceases and water boils.

Force System

In the force system the engine drives a pump which keeps the water in constant circulation. The pump forces the water from the bottom of the radiator to the inlet at the bottom of the water jacket, through which it flows to the outlet at the top. From here it goes to the top of the radiator and flows through the radiator to the bottom. As it passes through the radiator tubes it is cooled. After passing through in this manner it is again drawn to the pump.

Circulation Pumps

Practically all pumps are driven by a gear on the crank shaft or cam shaft, so that the motion is positive and there is no slipping. There are three types of circulation pumps in use: the gear type, the centrifugal type and the rotary type.

The Gear Pump

The gear pump consists of two small gears with large teeth, the two gears being in mesh and placed in a casting that fits the gears as snugly as possible. The water enters at one side, where the teeth come together, is carried around to the opposite side in the spaces between the teeth, where it escapes through the outlet.

The Centrifugal Pump

The centrifugal pump acts on the principle of an air blower, and has blades projecting from the hub which revolve at high speed inside of a casing. The water enters at the hub and is thrown outward by the blades to the outer casing.

The rotary pump consists of a ring-shaped casing, within which a disc revolves, the disc being eccentric or to one side of the center of the casing.

Through a slot across the disc are two arms, and their ends are pressed against the casing by springs. As the disc revolves the water is forced from the inlet to the outlet by the arms.

Radiators

Radiators must be used with either the thermo-syphon system or the force system. They are usually placed in front of the engine and mounted on the frame; but in a few cars they are placed back of the engine next to the dash

There are numerous modifications in radiators with two leading types. The cellular and the tubular. There is a third type in which the water circulates as in the tubular radiator, but whose general appearance is much like that of the cellular radiator. This is the radiator in which zig-zag pipes are arranged vertically. It should be classed as a tubular radiator, although it is often called the honeycomb.

A tubular radiator is one composed of a series of tubular water passages These tubular passages may be arranged horizontally, vertically, or at an angle. They may be also bent in a zig-zag fashion that brings about a combination of the horizontal and vertical and a consequent oppositely disposed angular flow of water through the tubes. The object is to imitate or bring about the appearance of the cellular construction.

A cellular or honeycomb radiator is one composed of a large number of individual air cells, any of which may be removed and replaced by another in case of leakage. The air cells may be entirely surrounded by water when the radiator is in operation; and the course of the water circulation through the radiator is not confined to any definite horizontal, vertical or angular course.

In order to cool the water sufficiently, a fan driven by a belt or chain from the engine was formerly attached to the radiator, but is now always attached to a special bracket on the engine. The fan is usually driven by a leather belt, from a pulley on the end of the crank shaft. The belt can be tightened either by raising the fan or by an eccentric adjustment, or by bodily lifting the fan and its bearing and tightening a bolt holding it. The bolt should be kept tight. Ball bearings are usually provided for the fan and they should be kept well oiled.

The fan draws a current of air through the passage in the radiator, in addition to that driven through it by the forward movement of the car. There are two types of fans in general use, the 4-blade and the 2-blade type.

Hose Connections: This is one of the most important items under water cooling systems. Hose connections are made of a fabric covered with rubber, so designed as to withstand the moving or the cooling piping getting out of line. At the top of the radiator a pipe is welded on and a rubber hose is used to connect it with the pipe on the top of the engine. On the bottom of the radiator there is also a pipe which is connected by means of a rubber hose to the bottom of the engine watercooling chamber (if it is the thermo-syphon system) or to a water pump.

The water pump is connected to the cooling chamber on the engine by a rubber hose connection.

These rubber hose connections are held water tight by a band clamped around the hose and a small bolt to adjust the clamp.

Due care must be taken that these clamps do not cut the rubber hose.

Water System

Causes for water boiling are numerous. One of the most frequent causes is compression leaks. A very rich mixture is inclined to heat the motor and makes it logy.

Hose connections are always fastened by a ring clamp at each end. The inside of the hose is coated with grease. If an old piece of hose is used shellac is generally used. All hose connections must be kept tight at all times.

There is always a fan directly behind the radiator to draw the air through and cool the water. Fans are usually belt-driven from the cam shaft by means of a pulley.

Knocks: It is very necessary for the driver to distinguish the difference between a motor knock and a carbon knock.

a. Carbon knocks are sharp metallic raps that come when the motor is pulling hard or when the spark is advanced too far.

b. A motor knock may be caused by any of the following: Loose connecting rod bearing, loose main bearing, loose wrist pin. All of these knocks have a heavy dull thud. There is another light knock due to the adjusting end of the tappet being low. This is rather a sharp knock and comes regularly at each turn of the motor. A knocking motor should be turned over to the master mechanic at once. When a connecting rod gets loose, it is liable to break and go through the crank case.

Motor Truck Company Drivers' Course
LABORATORY

LECTURE II

MEANING OF CARBURETION

The mixing together of gasoline vapor and air is called carburetion and the device that keeps the two in proportion is called a carburetor. Gasoline must be converted into a vapor and then mixed with a volume of air before it can be exploded in the cylinder and produce energy.

There are two ways of producing this vapor. One is to expose a considerable surface of gasoline to the air, which is caused to bubble through the gasoline and to thus become saturated with the gasoline vapor. This was the original method and was called the surface type of carburetion.

The second method is to spray the liquid gasoline through a fine spray nozzle or jet into the mixing or vaporizing tube, through which air is drawn to intermingle with the vapor. The device in which this operation is performed is termed the carburetor and the operation itself is known as carburetion from the fact that the gasoline consists largely of carbon. The mixture might also be termed carbureted air.

Amount of Gasoline and Air

It has been found that the best explosive mixture with the gasoline commonly used, when the maximum power is desired is a proportion of 4 parts air to 1 part gasoline vapor. The proportion may range to 17 to 1, which is for maximum economy. Pure gasoline vapor cannot burn; it must be mixed with air before it can be used in an engine. In order that it may burn with the greatest rapidity and heat, the air must be in correct proportion to the vapor. The exact amount of air to be mixed with a certain amount of vapor depends on the quality of the gasoline and on other conditions. The carburetor by which the proportion of the mixture is maintained is so made that a current of air passes through it when the piston makes a suction stroke.

The air goes through this passage, in which is a small pipe called a spray nozzle that sprays the gasoline so that it comes in contact with the air. The gasoline, being volatile, is taken up by the air and the mixture goes to the cylinder. The amount of air which may flow through the carburetor, and the quantity of gasoline that may flow out of the small pipe, are adjusted, so that for a certain amount of gasoline the correct proportion of air is admitted.

When the mixture is not correct, that is, when there is too much or too little air for the gasoline flowing out of the small pipe, the running of the engine is affected, and it does not deliver its full power. When there is too much air for the gasoline, the mixture is said to be too poor or lean; and when there is too little air, the mixture is said to be too rich.

The carburetor is connected to the intake manifold and no air nor gas can enter the cylinder through the intake valve without first passing through the carburetor. The air drawn through the carburetor on the suction stroke enters it through the air intake around the spray nozzle, drawing the gasoline

with it. The level of the gasoline in the float chamber then drops, and the float also drops and permits more gasoline to enter the float chamber.

It is in the mixing tube or mixing chamber, as it is sometimes called, that the air is brought into contact with the gasoline. The spray nozzle projects into the mixing tube so that it is in the center of the current of air.

How the Gasoline is Drawn Into the Cylinder With the Air

When the air is not passing through the mixing tube, the liquid gasoline stands just below the open end of the spray nozzzle, but as soon as the air current passes through, it takes the gasoline out. The current of air sucks the gasoline as a child trying to draw the last drop of soda through a straw, draws in really more air than soda. The piston of the engine, on its suction stroke, produces the suction effect similar to a squirt gun drawing in water. The inlet valve must open to permit the gas to be drawn into the cylinder, if the piston is on the suction stroke, but not on any other stroke.

The adjusting screw or gasoline needle valve regulates the amount of gasoline to be admitted to the mixing tube through the spray nozzle or jet. The regulation of this needle valve is very important and after it has been once properly adjusted, a very slight turn one way or the other will affect the running of the engine.

The throttle valve, usually placed in the mixing tube, above the spray nozzle governs the amount of gas which enters the cylinder on the suction stroke. The throttle valve lever on the carburetor connects with the throttle lever on the steering wheel. Moving the throttle lever on the steering wheel, in a certain direction, opens the throttle valve on the carburetor and this increases the speed of the engine. The more gas that is admitted by the throttle lever through the throttle valve, the more gas enters the cylinder, and produces more power or greater force on the power stroke. Moving the throttle in the opposite direction closes the throttle valve on the carburetor, reducing the amount of gas which enters the cylinder, thereby reducing the speed of the engine. The float, in the carburetor, is provided merely to prevent the gasoline from overflowing and running out of the spray nozzle, when the engine is not running. The float is adjusted so that the level of gasoline does not quite reach the top of the spray nozzle or jet. The floats are usually made of cork or hollow metal balls, which float in the gasoline inside of the float chamber. A needle point arrangement is connected with the float which cuts off the gasoline flow when the engine stops.

The reason engines must first be cranked before starting is that an initial charge of gas must be drawn into the cylinder and then compressed. Compressed gas is ignited by the electric spark and this produces the power stroke. The power from this combination of compressed gas, together with the momentum of the flywheel, keeps the engine in motion until the next power stroke. The cycle of suction, compression, power and exhaust is repeated over and over.

Fuel Systems

There are two, gravity and vacuum. A gravity system is where the float chamber of the carburetor is lower than the lowest part of the gasoline tank, so that there will be a constant flow of gasoline to the carburetor. In this system the tank is placed under the front seat or on the dash.

The Vacuum Feed System.—Several systems have been developed in which the gasoline is transferred from the main tank at the rear of the car by vacuum, or suction, to a small auxiliary tank near the engine. From this small

tank the gasoline flows by gravity to the carburetor. This system comprises a small cylindrical tank, mounted on the engine side of dash. This tank is divided into chambers, upper and lower. The upper chamber is connected by a small pipe to the intake manifold, while another pipe connects the small tank with the main gasoline tank. The lower chamber is connected with the carburetor.

The intake strokes of the motor create a vacuum in the upper chamber of the vacuum tank, and this vacuum draws gasoline from the supply tank. As the gasoline flows into this upper chamber, it raises a float valve. When this float valve reaches a certain height, it automatically shuts off the vacuum valve and opens an atmospheric valve, which lets the gasoline flow down into the lower chamber. The float in the upper chamber drops as the gasoline flows out, and when it reaches a certain point, it in turn reopens the vacuum valve, and the process of refilling the upper chamber begins again. This process is repeated continuously and automatically. The lower chamber is always open to the atmosphere, so that the gasoline always flows to the carburetor as required and with an even pressure.

The amount of gasoline always remaining in the vacuum tank gets heat from the motor and thereby aids carburetion. It also makes starting easier, by reason of supplying warm gasoline to the carburetor. The lower chamber of the tank is constructed as a filter, and prevents any water or sediment that may be in the gasoline from passing into the carburetor. By means of petcock in the bottom of the tank sediment may be drawn off, or gasoline procured if required for priming or cleaning purposes.

Ignition.

The original method of igniting the gas in a gasoline engine was by means of a hot tube or flame but this method is obsolete.

The ignition systems used on automobiles at the present time are all electrical systems giving an electric spark which passes into the cylinder of the engine and sets fire to the compressed mixture. In the discussion of electricity and electrical apparatus in these systems, the first thing is to know how electricity acts and how it is made to work for you.

A water wheel in a pond does not revolve, no matter how large or how deep the pond may be. To produce any work the wheel must be placed in a position such that the water may flow from a high level to a low level, and in flowing move or push the wheel around. There must be a current of water before the wheel can move; so in electricity there must be a current or flowing of electricity before work can be produced from electricity.

To make water flow one must make a path for it downhill. Water can be pumped to a high level and then made to flow through pipes or along a stream. When water is pumped into a tank that is 100 feet high, there is a certain pressure in the pipes leading from the tank, that is measured in so many pounds pressure. At the same time the quantity of water flowing out of the pipes is stated in so many gallons flow per minute.

The student is, no doubt, familiar with the measurements called a pound, gallon, and minute. The statement that 300 gallons of water are flowing out of a certain pipe in a minute at a pressure of 50 pounds gives one a definite idea of the current of water.

In electricity, the measurements of electric current are not stated in pounds, but in other terms, as amperes, meaning the quantity of current flowing; volts, meaning the pressure; and ohms, meaning the resistance.

Electricity produced in one place may be transmitted to another place, provided a path is arranged so that it may return to where it started. It cannot flow if there is no circuit. If the circuit is broken, the flow immediately stops, and cannot start again until the circuit is once more completed. Copper wire is ordinarily used to conduct the electric current from where it is produced to where it is used; and another wire is used to bring it back again. The first wire is called the lead wire and the second, the return. If there is any way in which the current may leak from the lead wire and return to the starting point without going through the entire circuit, it does so. This leakage is called a short circuit.

Anything that permits electricity to pass through it is called a conductor. All metals are conductors. Substances such as rubber, china, porcelain, glass, wood fibre, and mica are called non-conductors or insulators. To keep the current of electricity from escaping, a wire is insulated by being wrapped with cotton or silk, which is soaked with rubber to prevent the dampness from getting in. When dry, cotton and silk are insulators; but as water is a conductor, damp cotton and silk cease to be insulators. While other metals are conductors, some are better conductors than others; a copper wire, for instance, passes a larger current of electricity than an iron wire of the same size, owing to the fact that copper has a lower resistance.

If a wire has more electricity passed through it than it can easily conduct, heat is generated, and it may get so hot that it melts. The larger a wire is, the larger is the current that it can carry without heating.

Copper is in most general use as a conductor of electricity, because it carries a larger current that almost any other metal. Silver is a better conductor, but is not used because of the expense.

A current of electricity flowing in a wire may be measured the same as a current of water flowing in a pipe. The amount of water that flows through a pipe depends on the pressure, or head, and the friction in the pipe. The volume of electricity that flows through a wire depends on the pressure at which it flows and the resistance of the wire.

An ohm is the unit of electric resistance. It is the resistance that limits the flow of electricity under an electro-motive force of one volt to a current of one ampere. For instance, we speak of a certain size of copper wire of a certain length having so many ohms resistance. Iron wire offers 6½ times more resistance to the flow of current than the same size of copper wire. If it is not of sufficient size to permit the free passage of the current, the wire heats.

The watt is the unit of electric power; 746 watts equal one horse power. Multiplying the amperes by the volts gives the watts.

The pressure of a current, or the force with which it flows, is measured in volts. Thus, a current of ten volts is flowing with a pressure of that amount, just as water in a pipe might be flowing at a pressure of ten pounds.

The volume of the current or quantity is measured in amperes. One ampere is the amount of current caused to flow through one ohm of resistance, under pressure of one volt. Usually the ignition system of an engine is made so that it will work with a pressure of six volts. The current must be high enough to make the apparatus work properly. The resistance that the electricity meets in the wiring of the ignition system is so great that if you had a pressure of only one volt this would not be sufficient to force enough current through the wires. As the pressure increases, the quantity of current that flows becomes greater. It has been found that a pressure of six volts is sufficient pressure for most ignition systems.

The way pressure is built up to six volts, with dry cells which give 1¼ to 1½ volts each, is by connecting them in series. This can be explained as follows: Suppose one has three pails of water, and suppose one has three dry cells, each of them giving a pressure of one volt. If the three pails of water are placed one on top of the other and connected, and an opening is made in the bottom one connected with a pipe, the pressure in the pipe is three times as great as if there were only one pail. There is three times the volume of water, consequently three times the weight and pressure. When the cells are connected so that the pressure in them is added, a series connection is formed because it corresponds to putting the pails of water in a series one above another. To make this connection the positive pole of one cell is connected to the negative pole of the other, and so on. The connection to the outside circuit is made by running one of the wires of the outside circuit to the negative terminal of one end cell, and the other outside wire to the positive terminal of the other end cell. Since there is a pressure of one volt between the positive and negative terminals of each cell, there is simply added the voltage of all the other cells to it, just as is added the pressure in the other pails of water to the first one when they are set on top of each other.

In the multiple or parallel arrangement of a dry cell, or of storage battery cells, all the positive terminals are connected and all the negative terminals or plates are connected. The effect is merely that of adding to the size of the cell or plate.

Take the analogy of the pails. There is another way in which the three pails of water may be attached to the pipe all on the same line, instead of one on top of another. In this case there is no more pressure in the pipe than with one pail; but there is more water, and water will flow out of the pipe longer than if it were attached only to one pail.

Connecting dry cells in series increases the pressure or voltage of the current of electricity, Connecting dry cells in multiple or parallel increases the volume of current or makes the same voltage flow a longer time.

Increasing the size of the plates in a cell lengthens the time during which the cells give a current of electricity. If one dry cell gives one volt for one day, three dry cells give one volt for three days if connected in multiple. If connected in series the three one-volt cells give three volts pressure for one day. In order, then, to get a pressure for the engine of six volts of electricity, with dry cells each giving 1½ volts, simply connect four cells in series; then there is obtained four times 1½ or six volts, pressure enough for the ordinary ignition system.

As the voltage has a tendency to drop when in use, six cells are usually placed in series. It is not well, however, to use more cells in series than are needed for good working, because the excess of pressure forces the electricity through the circuit at too great a rate and the high current damages the vibrators of the spark coils.

Electricity flows more easily through some conductors than through others, because there is a difference in their resistance to the current. Every thing presents more or less resistance to the flow of the electric current and the less resistance that a substance presents, the better conductor it is. The greater resistance, the less current can pass. The pressure of the current does not change, but the volume (amperage) is reduced. As a current is forced through such resistance, heat is produced; and the greater the resistance, the greater is the heat.

Positive and Negative Terminals.—Every generator of electricity has two terminals, that being the name given to the points from one of which the cur-

rent leaves and to the other of which it returns. The current always flows in the same direction, from the positive pole to the negative pole; it leaves the generator by the positive pole and returns by the negative pole. Connections can be grounded from either the negative or the positive pole. It makes no material difference from which. Manufacturers as a rule ground the positive terminal of a storage battery to the frame.

Electricity and High Tension Coils

Flow of Current.—The current flows only when the two terminals or poles are connected by a conductor. A current flows if any opportunity is presented. If there is no regular conductor, moisture often makes the connection.

If the circuit includes a coil or lamp, the current in flowing through the circuit from the positive pole to the negative pole is made to light the lamp or pass through the coil. The circuit, with the lamp or coil, presents a resistance to the flow of the current. If there is a short circuit that presents less resistance, the current returns by it instead of going through the coil or lamp. Therefore, the circuit must be so arranged that the current cannot return to the generator without doing the work set for it.

A switch is provided to close the circuit, when work is desired, and to open the circuit when work is not desired. For ignition, instead of a switch, a timer or commutator is made to open and close the circuit at the time the spark is required.

Parts Necessary to Produce Ignition Spark.—While there are several methods of producing the spark in the cylinder at the proper instant, they are in general the same. In the first place, there must be a generator to supply the current of electricity; spark plugs or sparkers in the cylinder, at which the spark is produced; a timer by which the exact instant of spark may be controlled; and the circuit, consisting of the necessary wires or conductors.

Whatever the system may be, the current is produced by some kind of generator; and therefore, a description of generators will be given before a description of the systems.

Generating Direct Flow Current.—A current of electricity may be generated by chemical means, by cells; or by mechanical means, by a magneto or dynamo.

Chemical Generators.—Cells are of two kinds, primary and secondary. Primary cells actually make the current, and secondary cells store the current and give it out as needed. A dry cell or storage battery cell produces a direct flow of current and is termed a chemical source of electricity.

The primary cells used for automobiles are called dry cells, and consist of zinc cups, in which are placed sticks of carbon. The cups are lined with some substance like blotting paper, and the space is packed with bits of carbon and the necessary chemicals. The blotting paper and carbon bits are moistened with the proper solution, and the top of the cup is sealed with tar, so that it is water tight. The zinc cup and the carbon stick have a thumb nut at the top, called a binding post, to which the wires are attached.

When the circuit is closed, the current of electricity flows from the carbon binding post, through the circuit and back to the cell, by the zinc binding post. The carbon is the positive post and the zinc the negative post in this type of cell. Dry cells have a pressure or voltage, of about 1 ½ to 1 ¼ volts; and the volume of the current they produce, called the amperage, depends on the size of the cell. The ordinary dry cell used in automobile work gives from 20 to 30 amperes. Dry cells are used for starting, but for the continuous

running of an engine they too soon become exhausted. They are intended for intermittent use only.

For continuous current service the most efficient means of obtaining current is by means of a storage battery, a battery of secondary cells, or, as it is sometimes called, an accumulator. Secondary cells, also called storage cells or accumulators, are usually charged with current from a lighting circuit, and may be recharged when exhausted.

A storage cell is made of prepared lead plates, placed in jars of hard rubber or celluloid and filled with a solution of sulphuric acid and water, called the electrolyte. Electrolyte is made by adding one part of chemically pure sulphuric acid to from three to nine parts of pure water. Distilled water should always be used if at all possible. The jar is filled with electrolyte until the plates are covered about ½ inch over the top of the plates, and a cover is provided to prevent the solution from spilling. A hole in the cover, closed with a plug, is used for examining the condition of the cell and for refilling when necessary. Through evaporation, leakage, or spilling, the level of the electrolyte may get below the top of the plates, in which case the jar should be refilled, enough electrolyte being added to bring it to the correct level.

Mechanical Generators.—The action of a mechanical generator, which is driven by the engine, depends on magnetism, which is the property sometimes possessed by iron or steel, by means of which these metals attract other pieces of iron or steel. A generator consists of two parts; the poles through which the magnetic field flows, and the armature which revolves in this magnetic field and produces the current of electricity.

The field is made in one of two ways; it is either a permanent magnet, that is, steel that is magnetized so that its magnetism does not change, or an electro-magnet; that is, wire wound around a soft piece of iron, which is a magnet only while electricity is flowing through the wire. When the field is a permanent magnet, the generator is called a magneto. When the field is an electro-magnet, the generator is called a dynamo. The voltage of a magneto or a dynamo depends on the size and quantity of wire wound on the armature and field, on the coils, and also on the speed at which the armature is rotated.

Ignition Systems.—There are two systems of ignition used for automobile engines, the low tension system and the high tension system, the source of electric supply being either by chemical means, as dry cells or storage battery, or by mechanical means, as a magneto or dynamo. The word tension means pressure or voltage; high tension is high voltage, and low tension is low voltage.

The low tension system of ignition is used on only a few makes of automobiles.

The high tension system of ignition is the approved system now in use on very nearly all makes of cars. The high tension system may comprise a high tension coil and a battery; a high tension coil and low tension magneto; a high tension coil and dynamo in connection with a battery; or a high tension magneto alone.

A spark plug is screwed into each cylinder of the engine. When the piston is in the right position to receive a spark, a current of electricity is sent along the metal center of the spark plug and across the small air gap space at the bottom and into the outer sleeve of the plug. Although this gap is only 1/64 to 1/32 of an inch wide, the air in the gap offers such a tremendous resistance to the current that it requires in the neighborhood of 20,000 volts

pressure to force a very small quantity of current across the gap. In other words, the current must be of such high pressure that it jumps across the space between the two points, forming a spark at is passes.

The current produced by a battery and low tension coil as used for the make and break system, does not have enough pressure to jump across the gap, therefore it must be intensified. Where simple low tension coils are used for the make and break system, coils of another kind, called high tension coils, are used to intensify the current enough to force it to jump across the open space. Therefore, these coils are called high tension.

High Tension Coil Construction.—An induction coil or jump spark coil consists of a core of soft iron wire, over which are wound a few layers of coarse insulated copper wire, which is called the primary winding. Over the primary winding are wound a great number of layers of exceedingly fine copper wire, insulated, called the secondary winding. When a current of electricity flowing through the primary winding from some source of electric supply is suddenly stopped and started again, another current of great pressure flows in the secondary winding, although the two windings are not connected. This is called induction or temporarily induced current. This induced current in the secondary winding is called the secondary current. It flows in waves, there being a wave of current whenever the primary or battery current is stopped and started by a contact breaker of some sort.

Elementary Principles of a High Tension Coil.—The reason for this separate current flowing in the secondary winding can be understood only after studying electrical engineering. One may, however, understand the elementary principle of magnetism, lines of force, and induced current, also the relation of volts and amperes to cell connections. In order to produce a spark in the cylinder of a motor strong enough to ignite the compressed gas, it is necessary to have the current producing the spark under great pressure. The pressure or voltage of a storage battery or a number of dry cells is not enough; therefore, this pressure must be made greater.

Raising the voltage of the battery current is accomplished by means of an induction coil (high tension coil) called a spark coil. In order to understand the induction coil a few elementary steps must be learned first.

An ordinary horseshoe magnet is known to attract iron and steel. The magnet has a holding effect on the iron or steel even if the magnet is separated from the iron by a piece of paper or glass. If a number of iron filings are attracted by a magnet, it will be noticed that the filings arrange themselves in rows from one pole of the magnet to the other. It is supposed that the filings arrange themselves in lines because the magnetism goes from pole to pole, or end to end, in lines. These lines are invisible and they are called lines of force. Magnetism is accordingly expressed in lines of force. All the lines of force between the two poles of the magnet comprise a magnetic field.

The magnetic lines of force manifest themselves not only around a magnet, but around any current-carrying wire. This can be easily proved. If a compass is held near the wire, the needle of the compass suddenly takes a turn and then remains still. The current passing through the wire causes magnetism to exist around the wire for a certain distance, and this magnetism, acting upon the steel of the needle of the compass, causes it to turn. If this simple experiment is tried, it is found that the compass needle turns in the direction of the flow of the lines of force around the conductor. It should be borne in mind, then, that around every conductor of electricity there are lines of magnetic force or a magnetic field.

The magnetism from the magnet is called natural magnetism. Magnetism may be produced in another way, by the use of what is called an electro-magnet. Consider an iron bar which has packed around it some paper or other insulating material. A coil of copper wire is slipped over the iron, which is called the core. The two ends of the coil of wire are attached to a number of dry cells, connected in series. If a piece of metal, such as steel is placed near the end of the core, it is attracted by the core. If the wires from the battery are removed, the pieces of iron or steel at the end of the core are no longer attracted. In other words, as soon as a current is passed through the copper coil, the iron core is magnetized; but as soon as the current stops flowing, the magnetism stops. This magnetic field pierces anything. This is here evident because the core is insulated by paper. It could just as well have been wood or glass or stone.

It has just been shown that the current flowing through a coil of wire affects an iron bar within it so as to make the bar become a magnet. It also affects another wire placed alongside of the wire carrying the current. These same lines of force which make a magnet out of a piece of soft iron set up another current of electricity in another wire close to it, which has no electrical connection with it.

That is, suppose one takes a coil of wire and attaches the end of the coil to a battery and then winds another coil of wire around this first one and insulates it from the first. It is then found that every time the current in the first coil, the one connected with the battery and called the primary coil, is interrupted, or commences to flow, there is a current set up or induced in the other coil.

So long as the current in the first coil continues without change or interruption, it does not set up an induced current in the secondary coil. The current is induced in the secondary coil only when the flow of current in the primary coil changes, usually by the opening or closing of the circuit. The effect of the primary coil upon the secondary has been found to be increased if a bar of soft iron is placed inside the two coils.

The secondary current acts in the same manner as the primary current; that is, it flows through wires. It can be made to do work, the current leaving the secondary winding at one terminal and returning to the other. The difference is that it has exceedingly high pressure, voltage, and little volume, amperage, and flows in the reverse direction; while the primary current has low pressure and great volume.

When the circuit of the primary coil, which is connected with a source of electric supply of some sort, is closed and opened suddenly, the current is induced in the secondary winding, and at the same time it is intensified. In other words, the voltage is raised so high that it jumps a gap.

Electrical Units and Relations.—The electrical units are derived from the following mechanical units of the metric system:

Centimeter-Unit of Length.—One thousandth millionth part of a quadrant of the earth's surface.

Gram-Unit of Weight.—Weight of a cubic centimeter of water at a temperature of 4 degrees centigrade at sea level.

Second-Unit of Time.—The time of one swing of a pendulum making 86,400 swings in a solar day.

The Unit of area is the square centimeter. The unit of volume is the cubic centimeter.

The electrical units are as follows:

Volt—The Unit of Electro-Motive Force.—Force required to send one ampere of current through one ohm of resistance.

Ohm—The Unit of Resistance.—The resistance offered to the passage of one ampere when impelled by one volt.

Megohm.—1,000 ohms.

Ampere—Unit of Current.—The current which one volt can send through a resistance of one ohm.

Coulomb—Unit of Quantity.—The amount of current delivered by one ampere flowing for one second.

Farad—Unit of Capacity.—Capable of holding one coulomb.

Microfarad.—One-millionth part of a farad.

Watt—Unit of Power.—The power possessed by one ampere under pressure of one volt passing through one ohm. 746 watts equal one horse power.

Joule—Unit of Work.—The work done by one watt acting through one second.

Ohm's law states that the current in any system of conductors equals the electro-motive force divided by the resistance or,

Electro-motive force equals the current multiplied by the resistance or,

Resistance equals the electro-motive force divided by the current flow.

Electro-motive force varies directly as the current and as the resistance. Resistance varies directly as the electro-motive force and inversely as the current. Current varies directly as the electro-motive force and inversely as the resistance.

A horse power is the power required to raise 33,000 pounds one foot in one minute, or 550 pounds one foot in one second. It is equal to 2,545 heat units (B. T. U.) per hour, 42.4 heat units per minute, or .707 heat units per second. It is equal to .175 pounds of carbon oxidized per hour or 2.64 pounds of water evaporated from 212 degrees Fahrenheit per hour. It is equal to 746 watts of electric power.

The Vibrator and Magneto

The secondary current of a coil flows only when the primary current begins to flow, or is suddenly interrupted. Therefore, there must be an arrangement that completes the primary circuit, causing the battery current to flow through the primary winding, and then to break the circuit, so that the battery current stops flowing or is started flowing.

This arrangement which opens the circuit is called the vibrator. It may operate in two different ways: electrically and mechanically.

The Mechanical Vibrator

The mechanical vibrator is used principally on single cylinder motorcycle engines. It consists of a flat spring with a small weight on one end, the other end being attached to a post. The weight rests on the iron rim of a small cam, with a notch in it; so that when it turns, the weight drops into the notch. One wire from the primary circuit is attached to the flat spring and the other wire of the primary to an adjusting screw.

When the weight, called the bob, is in the notch of the cam, the spring makes contact with the adjusting screw and the current flows; but the cam in continuing to turn moves the weight out of the notch, separating the flat spring from the screw and breaking the circuit. The flat spring vibrates when

the weight drops into the notch, making and breaking the circuit in this way. The primary current flows through the primary winding in waves, flowing and stopping each time that the vibrator makes and breaks the circuit. It thus produces a corresponding current in the secondary winding, called an induced current, as previously explained.

The Magnetic Vibrator.—The magnetic vibrator depends on the magnetism produced in the core of the coil when the primary current passes. A flat spring called the vibrator spring or blade, is so placed that one end of it is opposite the end of the core, the other end being firmly supported. Touching the vibrator spring near its free end is the point of the adjusting screw.

One terminal of the battery is attached to the adjusting screw, the vibrator spring is connected to one end of the primary winding of the coil; the other end of the primary winding is connected to the commutator, which is called a switch. When the commutator switches the current through the primary winding, the core becomes a magnet and attracts the free end of the vibrator spring, drawing it away from the adjusting screw. As soon as the attraction draws the vibrator spring out of contact with the adjusting screw, the circuit is broken. The current stops flowing in the primary coil, the core ceases to be a magnet, and the vibrator spring, being no longer attracted by the magnetism, springs back and again makes contact with the adjusting screw. This again closes the circuit and the vibrator spring is again attracted by magnetism. In this way the circuit through the vibrator spring and the adjusting screw is broken and made again, as long as the commutator keeps the primary circuit closed through its contacts.

The strength of the secondary circuit, and consequently the strength of the spark, depends on the correct adjustment of the vibrator spring by the adjusting screw. As the construction of the coil is very delicate, it is not expected of the driver to know more than just how to adjust the vibrator.

The high tension coil using a magnetic vibrator in connection with a commutator causes a succession of sparks instead of a single spark. The disadvantage of this type of coil is the possibility of the vibrator platinum points sticking, with a consequent missing of explosion. Another disadvantage is the fact that it makes several weak sparks, the hottest one igniting the charge. This causes slow ignition. A good single hot spark has proven the most effective, as used on the Delco and Atwater-Kent systems, employing a mechanical type of vibrator.

The Commutator.—Because the secondary current is needed only when it is time for the spark to pass and ignite the mixture, the primary current is switched into the primary winding only once during the revolutions (on a single cylinder engine). The switching is done by a commutator or timer.

Heretofore the words timer and commutator have been used to apply to the same device. The device which makes the contact by a brush or rolling contact is called a commutator. This device is always used in connection with a magnetic vibrator type of coil.

The timer is a mechanical method of causing the contact to be closed and opened. This device makes a single spark and is generally used in connection with a coil without a vibrator. There are two principles of the timer: first, when it is used to open the circuit which is otherwise always closed. This is called a closed circuit principle. The opening of the closed circuit interrupts the flow; therefore, it is termed an interrupter or contact breaker. Second, when the timer suddenly closes the circuit, which is otherwise always open, the principle is called an open circuit principle.

The commutator might be termed a revolving switch which brings two pieces of metal connecting the primary circuit in contact with each other as it revolves. One part of the commutator is stationary and the other movable, being attached to the half-time shaft (cam shaft). The usual location for a commutator on an engine is on the end of the cam shaft.

The commutator or timer is connected with the spark lever on the steering wheel. When the spark lever is pushed forward, the commutator is shifted forward so that the metal roller makes contact earlier with the contact segment; this is called advancing the spark. If the commutator is shifted back instead of forward, the contact is made later; this is called retarding the spark.

It is well to run with the spark lever as well forward or advanced as possible, thereby keeping up the speed of the engine and consuming less gas and creating less heat. If the spark lever is too far advanced, the engine pounds or knocks, because the ignition takes place before the piston is over the center. Actual practice is the most effectual way of learning the amount of advancing or retarding the spark by hand.

The high tension magneto not only is a mechanical generator or a substitute for the battery, but combines all the elements for a complete ignition system, except the plugs and switch.

It performs three separate essential functions as follows: generating the current, transforming the current to a high pressure, distributing the high tension current to individual cylinders. Besides these main functions, a number of minor functions have to be performed. The high tension magneto differs from the low tension magneto in only a few particulars.

The armature on the high tension magneto is wound with two windings, a primary and a secondary, whereas a low tension magneto has but one winding, the primary. The secondary winding on the armature of the high tension magneto takes the place of a separate high tension coil. This secondary winding, except at one end, where both it and the primary windings are grounded, is carefully insulated. The other end is connected to a collector ring mounted on the armature shaft. A carbon pencil or brush rubbing on this collector ring takes off the secondary current and leads it to the distributor brush.

This type differs from the low tension magneto in that the condenser which is employed in connection with the interrupter is usually built into the high tension magneto, whereas with the low tension magneto the condenser is used to intensify the spark at the point of the spark plug and to prevent excessive sparking at the end of the platinum points of the vibrator. If the sparking at the interrupter is permitted to continue, the points of the latter wear and become pitted and do not make good contact. A condensed consists of a number of conductors, often leaves of tinfoil, separated by paper covered with paraffin or mica. The condenser is usually located on the armature shaft to get it as close to the interrupter as possible. In some magnetos, for the sake of greater accessibility, and for other reasons, the condenser is located outside the armature in a stationary sealed box.

The purpose of a condenser is to decrease the momentum of the current when the circuit has been broken by the interrupter. The suddenness with which the impulse in the primary circuit occurs makes more intense the spark at the plug. Owing to inertia, the current in the primary coil tends to keep flowing after the circuit has been broken; and this tendency is overcome by the action of the condenser. That is, the condenser absorbs the current that tends to continue flowing after the circuit has been broken. This extra flow of current wears the end of the interrupter, thus decreasing its efficiency.

This continuous flow of current also hinders the occurrence of sudden impulses in the ignition circuit.

Owing to the fact that the secondary coil of the high tension magneto is located in the armature itself, it follows that it not only acquires an induced current, on account of the breaking of the primary current, but itself induces a current like that of the primary coil, only smaller in volume.

The high tension collector ring is a hard rubber ring with a brass ferrule surrounding it and against this ferrule a heavily insulated stationary carbon pencil bears. The hard rubber spool has flanges for the purpose of preventing the high tension current from escaping, by giving the current a long path to travel from the brass contact ring to the shaft. As hard rubber is less resistant than air, the current tends to travel over the surface of the spool instead of striking through it.

It has already been explained how the high tension current is induced in the secondary or fine wire winding of the armature as the movement of the current ceases in the primary winding. It remains to explain how this high tension current is distributed, in succession, to the four spark plugs of a four-cylinder engine.

The beginning of the secondary winding is connected to the end of the primary winding; and since one end of the primary winding is grounded, the secondary winding is grounded through the primary. The end of the secondary winding leads to an insulated contact ring at the driving end of the magneto. From this ring the current is taken off by carbon brushes. From the brush holder the current is carried through a spring contact conductor to the central distributing contact. The distributor consists of a disc of insulating material, in which are imbedded on the inner side one central cylindrical contact piece and four sector-shaped contact pieces. The distributor also comprises a shaft which carries a gear wheel meshing with a pinion on the armature shaft. The gear wheel has twice the number of teeth as the pinion, and the distributor shaft, therefore, makes one turn while the armature makes two.

The reason for driving the distributor at one-half the armature speed is as follows: the armature, as already stated, turns at the speed of the engine crank shaft. The magneto here described is for a four cylinder, four cycle engine. In such an engine each cylinder requires a spark once in two revolutions of the crankshaft. The distributor is therefore geared so that it makes one revolution to two revolutions of the crankshaft and establishes a connection between the high tension or secondary winding of the armature and the spark plug to each cylinder once in every two revolutions of the crank shaft.

The gear wheel carries a brush holder containing a carbon brush, which is adapted to make contact simultaneously with the central distributor contact, and with one of the similar distributor contacts. The distributor sectors are surrounded at the inside and outside by annular rings of a highly insulated material, since they carry the high tension current. Each of the four annular contact segments has secured to it a binding post on the face of the distributor disc. Each of these binding posts is connected by a high tension (highly insulated) cable to one end of a spark plug.

There are numerous methods of making the connections from the secondary winding on the armature. In the Bosch, a carbon brush pressing on an insulated ring is adopted, thus allowing the armature to rotate freely, and also enabling the induced current to be drawn off. The distributor is really a rotary switch, especially insulated and provided with the same number of contacts that there are engine cylinders. In any standard magneto made on this prin-

ciple the general construction is as follows: the magnets are of two, or usually three pairs, one magnet of each pair being super-imposed on the other. In some few magnetos three magnets are placed one over the other. The magnets are set to give correct north and south polarity. The ends of the poles embrace pole pieces of soft iron bored out to allow the armature to rotate quite freely, but very closely to the pole face; in some cases the clearance is only .002 inch.

The Armature.—The armature consists of an armature core of soft iron of H-shaped cross section, also referred to as a shuttle armature. This core of soft iron serves to form a bridge for the magnetic flux between the pole shoes, and also to carry the winding in which the current is induced. The best class of magnetos have their armature built up of stampings of soft iron, each insulated from the other by a thin film of varnish. This form of construction is known as a laminated armature core. It has the advantage over solid cast iron in that the electrical efficiency is higher through the absence of eddy currents, which, in the solid iron core, represent considerable waste of energy and cause heating. As a result of the breaking up of the core into thin sections, the eddy currents cannot circulate through the iron. In the case of the solid core, the iron should be annealed to render it as soft as possible, to obtain the best magnetic effect.

Armature Winding.—The armature core is first insulated with mica or similar material. Then it has several layers of heavy insulated wire wound upon it. To the end of this heavy wire is connected the beginning of a very fine wire, insulated with silk, which is wound on the core until the slot is filled almost to the height of the cylindrical portion. After this a wrapping of insulating cloth is applied, and bands are put around the circumference of the armature to prevent the wire and insulating material from flying out and coming in contact with the pole shoes when the armature is rotated at high speed. To the ends of the armature the steel shaft or spindle on which it rotates is fixed by brass and plates.

It is thus noted that there are really two windings on the armature (whereas the low tension magnet has but one winding), an inner winding of relatively few turns of heavy wire, and an outer winding of a large number of turns of fine wire.

The winding of heavy wire, or primary winding, serves principally for generating the current and is in connection with the fine wire or secondary winding. It also serves to multiply the pressure or voltage to such an extent that it produces a spark at the gap of the spark plug in the cylinder.

The Interrupter or Circuit Breaker.—To accomplish this breaking of the primary circuit at the proper time and then to close it again, a device known as a circuit breaker or interrupter is used. This is carried on the armature shaft opposite the driving end. It consists essentially of a stationary contact point and a universal contact on one arm of the bell crank; both of the so-called parts are mounted on a brass disc, which is securely fastened to the armature shaft and rotates with it.

The stationary contact is insulated from the supporting disc, while the movable contact is in metallic contact with it. The disc is grounded to the frame of the magneto by a carbon brush. The circuit breaker is surrounded by a cylindrical housing to the interior surface of which, at diametrically opposite points, are secured two steel cam blocks. Ordinarily the two contact points are kept in contact by a spring. As the disc rotates, the outer arm of the bell crank comes in contact with the cam blocks, whereby the contact points are separated momentarily.

The condenser consists of two sets of tin-foil sheets, sheets of opposite sets alternating with one another and being separated by sheets of insulating material. All the sheets of each set are metallically connected. One set is connected to the conductor leading from the primary winding to the stationary contact point, while the other set is grounded. In other words, the condenser is shunted across the interrupter.

The Safety Spark Gap.—This is practically a safety valve for high tension current. If a wire becomes detached from the spark plug or from the distributor so that the ordinary path of high tension current is barred, there is considerable damage if the current is not given some easier escape as provided by the safety gap.

A magneto must be so designed that it gives a sufficiently hot spark at a comparatively low engine speed. The ability to do this implies the ability to withstand generating a very large and hot spark and an enormously high tension at high engine speed.

The actual electro-motive force or tension produced in the secondary winding is, however, limited by the size of the spark gap in the spark plug. As soon as the tension reaches a point sufficient to jump this gap the discharge occurs, and there is no further increase in the electro-motive force. Suppose, however, that the terminals of the spark plug are bent too far apart, or that one of the high tension connections to the spark plug accidentally comes loose. Then there is no chance for the spark to pass in the ordinary way and the electro-motive force in the secondary winding, may build up current to such an extent as to puncture the insulation of the winding, thereby ruining the armature. To avoid this the safety spark gap is provided.

The safety spark gap consists of a little chamber formed on the armature cover plate with a top of insulating material. Into the top and bottom of this chamber spark terminals are set. The spark terminal in the bottom is, of course, grounded; and that in the insulated top is connected with a high tension contact brush by a strip conductor. The gap between the two terminals is longer than the gap on the spark plugs. Ordinarily no spark passes between the terminals; but if, owing to the conditions mentioned already, no spark can pass at the regular spark plug and the electro-motive force in the secondary winding attains an abnormal value, then a discharge occurs at the safety spark gap, thereby preventing the secondary electro-motive force from rising still higher and puncturing the insulation of the armature.

Cutting Off the Magneto Ignition.—It is also necessary to be able to stop the magneto from producing sparks when it is desired to stop the engine. To this end a sheet metal strip is provided which connects the stationary contact point of the circuit breaker and leads to a binding post on the circuit breaker housing. From this binding post a wire is carried to a switch on the dashboard. One side of this switch is grounded.

When the switch is closed, the current generated in the primary winding of the armature flows to the contact point, thence through the strip, the binding post, and the connecting wire to the switch. From here it passes through a wire into the framework of the car and returns to the beginning of the primary winding. The effect of this is that the primary winding is short circuited all the time and the opening and closing of the contact points have no effect. In technical words, the circuit breaker is cut out.

Finally the very great delicacy of the magneto construction must be emphasized. No one should attempt to overhaul or take apart or repair a magneto without first thoroughly understanding its various functions. It is recommended that the student secure descriptive circulars of several standard mag-

netos (secured from any maker on application) and study them further. Drivers in the service are not expected to be able to adjust and repair magnetos. Instead, after determining the magneto as the sourc of ngine trouble, the fact should be reported in order that a thoroughly competent magneto repair man may be directed to make the necessary adjustments.

All company mechanics, that is, certainly all chief mechanics, should be competent to adjust, at least, standard magnetos.

Ignition and Timing.

Since in the regular operation of the engine the charge is ignition just an instant before the top of the compression stroke, the magneto armature is set relative to the engine crank shaft in such a way that the maximum induction effect occurs at this moment.

It is, however, necessary to be able to vary the point in the cycle at which the ignition occurs, since, when the engine is cranked by hand, the spark must occur after the end of the compression stroke, or else the engine may kick back. With a self-starter, it is possible to start with slightly more advance than wtih a hand crank, because the self-starter turns the engine faster.

Advance and Retard of Spark.—To advance the spark is to cause the spark to occur earlier, before the piston is on top of the compression stroke. To retard the spark is to cause the spark to occur later. An engine that is cranked by hand usually has the spark set retarded, so that there is no danger of a kick back. The exact position to advance or retard is determined by running as far advanced as possible at all times until a knock is detected, and then by retarding until the knock disappears. The driver soon learns the exact position where the engine gives the greatest power.

Control of Spark.—Principle; as the spark occurs only when the primary circuit is broken by the opening of the platinum contacts, the timing of the spark can, therefore, be controlled by having these platinum points open sooner or later. This latter is accomplished by the angular movement of the timing lever. This movement gives a timing range of about 35 degrees. The spark is fully retarded when the timing lever is pushed as far as possible in the direction of rotation of the armature and is advanced when pushed in the opposite direction.

Magneto Spark Control.—In order to make it possible to vary the range of the time of the spark on a magneto, the circuit breaker housing is so arranged that it can be rocked around on its axis, being provided with a lever arm for this purpose. From this connection can be made to a spark timing lever on the steering post.

It is readily understood that if the armature shaft turns right-handed and if then the circuit breaker housing is moved through a certain angle in a right-hand direction, the contact points separate later, with relation to the position of the engine crank shaft. On the other hand, if the housing is moved in a left hand direction the circuit breaker point opens earlier. In this way the point at which the spark occurs can be shifted through an angle of about 35 degrees.

Coil and Battery System Control.—On the Delco and Atwater-Kent and similar systems, the advance and retard are obtained by shifting the housing surrounding the timer and distributor. There are three general principles used for the control of the spark: (1) by hand, (2) by automatic governor, (3) by fixed spark. In the control of the spark by the hand spark lever on the steering post this lever shifts the commutator. The automatic advance is probably

the most satisfactory, because the spark occurs just at the right time automatically, and there is no guessing as to just how far to advance or retard at various speeds. The fixed spark is sometimes used with a high tension magneto. In other words, the time of the spark is fixed at a certain position, usually advanced, and the contact breaker breaks at one position regardless of the speed of the engine. This system has not proven satisfactory on engines where the speed varies, but would be satisfactory if the speed of the engine were constant. The objection, however, is in starting, the liability of a kick, for the spark is necessarily placed advanced for proper running.

Setting the Time of Spark With a Magneto.—There are three general positions for setting the time for the spark to occur with the magneto: on top of the compression stroke, before the top, or after the piston passes down from the compression stroke. The last named is seldom used with the magneto. The usual plan with the standard type of magneto is to place the piston of No. 1 on top of the compression stroke. Set the interrupter at the retard position, then turn the armature by hand until the interrupter points are just starting to separate.

Another plan is, set the piston before the top of the compression stroke, say 22 to 24 degrees, and set the interrupter points starting to separate when the interrupter housing is in the advanced position.

Magnetos that have no battery current to control can be timed on the bench. Remove the breaker box cover, and note the breaking points. Mark the shaft and bearing, then mount the magneto and set the engine on top dead center of the compression stroke. When the engine is so set and the marks are line and line, connect the magneto to its gear and drive shaft.

Effect of Spark Control on Power Efficiency.—When a combustible mixture has been compressed in the cylinder by the rising of the piston and when the spark occurs, a very small portion of the mixture in the immediate vicinity of the spark is ignited. If the mixture is properly proportioned and properly compressed, the flame propagates rapidly throughout the entire combustion chamber.

When combustion takes place, intensely heated gases are formed, which in their effort to expand exert great pressure on the walls of the cylinder in the combustion space and on top of the piston. As a gas or a gaseous mixture is compressed, it becomes heated; the greater the pressure, the greater the heat. If a mixture is of the proper proportions, the greater the pressure the more rapidly it ignites, and the greater is the speed of the flame propagation or combustion.

On the other hand, as the pressure of a combustible mixture is reduced, it loses heat, and its speed or ignition and combustion is also reduced. Thus it must be remembered that to get the utmost efficiency out of a combustible charge, it must be ignited at or near the point of maximum compression.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

LABORATORY

LECTURE III

CLUTCHES AND GEARS

The word clutch as used in connection with automobiles indicates a device attached to cars having change speed gears of the sliding type. The clutch permits the engine to be connected with, or disconnected from the change speed gear, so that the car may or may not move while the engine is running.

The clutch is connected with, and disconnected from, the fly wheel or engine by a foot lever. When disconnected from the fly wheel of the engine, there is no connection between the engine and the rear axle. When the clutch is connected with the fly wheel of the engine, the power of the engine is connected with the rear axle, if the gears of the transmission are not in the neutral position. If the gears are in neutral position, the power of the engine stops at the end of the secondary shaft of the transmission.

Other types of transmission require clutches, but they are of special kinds, and will not be referred to in this lecture. The Ford, for instance, uses a different principle.

Because a steam engine has behind it the pressure of the boiler, it can be called on to supply much more than the regular horse power for short intervals. A gasoline engine has no reserve power to call on, and cannot deliver more than a fixed horse power. When the gasoline engine is required to start the car, it must overcome the inertia of the car. This may be greater than the power of the engine can accomplish, and the engine may be stopped instead of the car being started. If the clutch makes an immediate connection between the engine and the drive, the power of the engine has to overcome instantly the inertia of the standing car.

With the power of the engine coming from the revolving of the fly wheel, and the explosion that may be occurring in one of the cylinders, the engine is probably stopped instead of the car being started. If, however, the clutch is made so that the engine takes hold gradually, the inertia of the car is overcome, and it moves faster and faster as the clutch permits the engine to apply its power more and more. This is done by making the clutch in such a way that when it is applied it slips, instead of instantly making a connection between the engine and the drive.

When the clutch is thrown in, it connects the crank shaft of the engine through the fly wheel with the change speed gear through the clutch shaft. If the change speed gear is in neutral, with the gears out of the mesh position, the counter or secondary shaft in the gear case of the transmission revolves without moving the car.

Clutches have two chief parts. One part is usually the fly wheel, attached to the crank shaft of the engine; and the other part, the cone or disc or plate, is attached to the main shaft of the transmission.

When the two parts are separated, that is, when the clutch is thrown out by the clutch pedal, the two parts are independent of each other and the engine

can run without moving the car. When the two parts are connected, that is, when the clutch is thrown in by releasing the clutch pedal, the part on the transmission shaft is forced into a frictional contact with the part on the crank shaft or fly wheel, and held there by means of a powerful spring. The two parts, thus connected, force the change speed gear to revolve with the engine and to drive the car, if the gears are not in neutral.

The part on the crank shaft does not grip the part on the change speed gear shaft immediately, unless they are moving at the same speed. If they are moving at different speeds, as is usually the case, or if the part on the change speed gear is stationary, the two parts slip. This slipping continues until the two parts revolve at the same speed, when they bind together firmly. When out they must separate instantly.

A disc or any other type of clutch used with the gear type of transmission is placed in the same relative position, back of the fly wheel, between the fly wheel and the gear case. Although the construction may vary, the clutch principle is necessary on all cars.

The left foot pedal on all cars of standard design is the clutch pedal, the right foot pedal is the brake pedal.

There are four types of clutch in general use: the cone, disc, plate, and expanding type. The disc clutch, formerly called the multiple disc, is a clutch with more than three discs and can be a lubricated disc clutch or a dry disc clutch. A plate clutch is one wherein one plate is clamped between two others.

The cone clutch is built into the fly wheel, and the fly wheel forms one of its parts. The rim of the fly wheel is broad, and the inside of the rim is made slightly funnel-shaped, forming the surface against which the other part of the clutch presses.

The other part, called the cone, is, at its name indicates, cone-shaped, and fits into the funnel formed inside the fly wheel rim. The surface of the cone that bears against the fly wheel is often covered with leather to give good grip. The hub of the cone has a square hole, so that while it may slide on the square part of the clutch shaft which connects to the change speed gear sleeve, still the cone and shaft must revolve together. The forward end of the clutch shaft rests in a bearing formed in the hub of the fly wheel, so that it is supported, and yet may revolve independently of the fly wheel.

A heavy spring presses the cone against the seat formed in the rim of the fly wheel. When the foot pedal is pressed forward, the cone slides on the shaft away from the fly wheel, and separates from it, the spring being compressed. When the foot pedal is released, the spring presses the cone against its seat; and if the crank shaft and sleeve are not making the same number of revolutions, the cone slips. This friction makes the cone act as a brake on the crank shaft, slowing it. At the same time the cone sleeves are speeded up, so that the cone and fly wheel come to the same speed.

The power from the crank shaft of the engine is transmitted to the clutch through frictional connection with the fly wheel, thence through gears, thence through the drive shaft to the bevel gear drive on the rear axle. If the engine is running, the clutch may be in if the gears are in neutral. If the gears are in mesh with the engine running, then the rear axle revolves unless the clutch is out.

Therefore there are three methods of cutting off the power to the rear axle: (1) by stopping the engine, (2) by throwing out the clutch, (3) by having the gears in neutral. The usual method to stop the car and engine is to throw out the clutch, shift the gears to neutral, and apply the foot brake. After the car stops, turn off the ignition switch and stop the engine.

When starting the engine, place the gears in the neutral position by the hand shift lever. The engine may then be started without the car moving. To start the car after the engine is started: throw out the clutch with the foot pedal, shift the gears in mesh, usually to the lowest gear set, then gradually let the clutch in. The term, clutch in, means that the clutch is allowed to press into the fly wheel with the tension of the spring.

The term, clutch out, means that the clutch is held out by the foot clutch pedal. If the car is running and you desire to coast, throw out the clutch or disengage the gears.

When stopping, throw the clutch out by a movement of the foot pedal. Apply the service brake. Shift the gears into neutral and then let the clutch in. Since the clutch is used more than any other control on the car, study the meaning of clutch in and clutch out, and gears in neutral.

When the change speed gear is to be moved to a higher speed after starting, or at any time when the car is in motion or the engine is running, the clutch must first be thrown out for the gears can not be meshed with the center shaft revolving and the square shaft stationary. Withdrawing the clutch leaves the countershaft free to move.

The disc clutch consists of a number of discs which are pressed together when the clutch is in, friction between them causing one to drive the other. This type of clutch is very compact, and is frequently built inside of a metal housing cast to the engine frame. To illustrate the principle of the disc clutch, place a silver dollar between two silver half dollars, and squeeze them together, between the thumb and fore-finger of one hand. With the other hand, try to revolve the dollar without moving the halves. It requires only a slight squeeze to produce sufficient friction to make it impossible to move the dollar.

Multiple disc clutches are of two general types: those that operate in an oil bath and those that run dry,—called lubricated and dry types. The lubricated disc clutch runs in oil; its discs are usually alternate steel and bronze or all steel discs. The type that runs dry is usually of steel discs, one set of which is faced with a friction material of woven asbestos fabric.

The S. A. E. term the disc clutch a clutch with more than three discs.

The single plate clutch is a popular type of clutch. It is a variation of the disc type.

When a bicyclist wants to race on a level track, he gears up his wheel with a larger sprocket, so that one revolution of the crank takes him farther. Yet if he takes his wheel with the large sprocket on the pedal shaft, out on the road where there are hills, he must get off and walk or exert an extra lot of power. This clearly shows that if a bicyclist wants to speed while on the level and yet take all hills, he must change the drive sprocket.

The same principle applies to the automobile. Therefore, the automobile not only is provided with two changes of gears but has three and sometimes four changes of gears. These gears are contained in a gear box usually placed back of the clutch. The principle upon which all change-speed gears work is the fact that when two cogwheels or spur gears are meshed together, the larger wheel turns more slowly than the smaller wheel. For example, a cog-wheel with ten cogs, in mesh with a second wheel having twenty, revolves twice as fast as the latter. The explanation is that when the cogs of the smaller wheel have moved round once they have engaged with only ten cogs of the larger wheel, and therefore will have turned the larger wheel only half a revolution; that is, it is necessary for the smaller wheel to revolve twice in order that the larger one may revolve once. In the gear box there are two shafts,

the upper one coming from the engine through the clutch, and the lower one continuing to the back axle.

Each shaft is fitted with three different sized cog-wheels. Those of the upper shaft are fixed to the shaft itself; but those of the lower shaft are able to slide on a keyway, along the shaft. The shaft is not round like the upper one, but is square; so that, although the sleeve of cog wheels can slide backward and forward, they cannot revolve independently of the lower shaft. In order now to vary the speed gear of the car, it is necessary only to slide the cog wheels along the lower shaft until the correct two wheels come into mesh to form the gearing required. The number of revolutions made by the engine to one of the wheels is different with different manufacturers, but as a general thing, when on the low speed the engine makes from 12 to 18 revolutions to one of the wheels, and on high speed from one and a half to four revolutions to one of the wheels.

The sides of the teeth of the gears are usually made like the point of a chisel, so that when two gears are brought together they mesh exactly. If the sides of the teeth were flat, as in ordinary gears, it would be difficult to slide them into mesh. When the gears are being shifted from one speed to another, the clutch in the fly wheel must always be thrown out.

With the clutch in the fly wheel thrown out, the sliding gear on the square shaft is free to move and its speed may easily be changed. If the change is made with the engine driving the upper shaft, changing the speed of the gear requires the speed of the engine to be changed; or changing the speed of the gear on the square shaft requires the speed of the car to be changed.

When a gear is in neutral, the gears are not meshed or in engagement at all.

It is always necessary in shifting gears, first to throw the clutch out of engagement with the fly wheel, then to bring the gears to neutral position, and then to shift from a lower to a higher gear, unless the car is gradually slowing down. In the latter case a shift to lower gear is in order. But never shift to a lower gear when running at high speed, as there is a liability of stripping the teeth from the gears; or if the teeth are strong enough to stand it, the car is badly jolted. Therefore, always throw out the clutch in the fly wheel before changing gears and let the car slow down if shifting to a lower gear. It is seldom, however, that a shift to lower gear is made unless the car slows down.

To Reverse Motion of Car.—The reverse gear must never be used until the car is at a dead stand still.

The location of the gear box may be either in front, adjoining the clutch, or on the rear axle housing. The modern method is the unit power plant, where the transmission and the clutch are connected to the engine as one unit.

The Selective Gear Type Transmission.—This type is preferable on account of the absence of noise and the ease of operation. The gear change ratio desired is selected by the gear shifting lever and the shift can be accomplished without one gear passing through another.

General Lubrication of Disc Clutch.—At the end of 500 miles the oil in the disc clutch should be removed, after which the clutch should be rinsed out with kerosene, and the housing thoroughly drained. Then the light clutch oil should be put in until the level is about even with the bottom of the clutch shaft. This does not, of course, apply to dry disc clutches.

Universal Joints and Drive Shaft

The use of one or more universal joints between the power plant and the rear axle is necessary, in order to provide for the lower position of the rear axle

and also to allow for the spring action between the axle and the frame which carries the power plant. A square block in the center of the universal joint fits between the jaws of two forks, one of which is connected to the power plant and the other is attached to the end of the drive shaft. The flexible connection of these forks to the block permits the drive shaft to oscillate freely with the rear axle and yet continue to receive and transmit power. The universal joints must be kept packed in grease at all times.

LECTURE IV

TYPES OF POWER PLANT

There are three types of Power Plant: unit, separate and combined. Unit is where motor, clutch and transmission are combined. Separate is where the transmission is hung between the motor and rear end. Combined is where the transmission and differential are together on the rear end.

There are two classes of Transmission: planetary and selective.

Planetary.—A planetary transmission is where the power is transmitted by means of bands. These bands have to be tightened and adjusted as they wear very quickly. The bands are operated by means of foot power.

Selective.—Selective is where the gears are selected by means of a change speed lever, and your speed is selected in this manner. The speed of the car must be figured before the change gear is made.

Change Gears Stick.—If the change gears stick when an attempt is made to shift from one gear to another, the shifting members may be bound on the shaft. If the gears have become burned or teeth are broken out, the particles of metal may prevent the movement of the sliding member. Occasionally the shifting lever becomes stuck and refuses to operate the gears. Under ordinary conditions, the change gears should give very little trouble if due attention is given to their lubrication.

How Planetary Gearing Operates.—The planetary or epicyclic transmission is an easily operated form of speed gear that has been very popular on small cars. This has many features of merit, it provides a positive drive, and as the gears are always in mesh these members cannot be injured by careless shifting. Individual clutches are used for each speed and as the operation of the clutch occurs at the same time that the desired speed is selected the various speed changes may be easily effected by manipulating a single lever.

A typical planetary gearing of simple form which was formerly used on the Oldsmobile, one of the earliest makes of car to be manufactured in large quantities. The gearing is carried in drums which are adapted to be revolved independently of each other or to be clamped by some form of clutch which would cause them to revolve as a unit with the crank shaft. The drive is by single chain from a sprocket carried between the brake and reverse drum and the gearing was mounted on a crankshaft extension which projected from the flywheel of the motor. The drum nearest the fly wheel carries three pinions which mesh with an internal gear member secured to the sprocket and with a gear driven by the flywheel hub. The slow-speed drum is provided with four pinions which are carried around by a disk which is also secured to the driving sprocket. In the reverse gear combination the disk that carried the pinions was provided with the brake member, while in the slow speed gearing it was the internal gear which was held from turning when the slow-speed ratio was desired.

The master clutch, which provided the direct drive, consisted of four fingers provided with leather friction pads which were forced against the face

of the internal gear drum of the slow speed by means of clutch dogs expanded by a sliding cone. When the clutch cone was forced in so that the small bell cranks brought the friction pads in contact with the face of the slow-speed drum, the entire assembly was firmly locked to the crank shaft and a direct drive obtained as the sprocket turned at the same speed as the engine shaft.

Why Change-Speed Gearing Is Necessary.—Those who are familiar with steam or electricity as sources of power for motor vehicles may understand the necessity for the change-speed gearing which is such an essential component of the automobile propelled by internal combustion motors. In explaining the reason for the use of the clutch it has been demonstrated that steam or electric motors were very flexible and that their speed and consequently the power derived from them could be varied directly by regulating the amount of energy supplied from the steam boiler or the electric battery, as the case might be.

If, for example, we compare the steam motor with the explosive engine it will be evident that the power is produced in the former by the pressure of steam admitted to the cylinders as well as the quantity and the speed of rotation. When the engine is running slowly and a certain amount of power is needed more steam can be supplied the cylinders and practically the same power obtained as though the steam pressure was reduced and the engine speed increased. The internal combustion motor is flexible to a certain degree, providing that it is operating under conditions which are favorable to accelerating the motor speed by admitting more gas to the cylinders. There is an arbitrary limit, however, to the power capacity or the mean effective pressure of the explosion, and beyond a certain point it is not possible to increase the power by supplying vapor having a higher pressure as is possible with a steam engine.

In an explosive motor we can increase the power after the maximum throttle opening has been reached only by augmenting the number of revolutions. Whereas it is possible to gear a steam engine or an electric motor directly to the driving wheels, it is not possible to do this with a gasoline engine, and some form of gearing must be introduced between the motor and the driving wheels in order that the speed of one relative to the other may be changed as desired and the engine crank shaft turned at speeds best adapted to produce the power required, and to allow the rear wheels to turn at speeds dictated by the condition of the roads or the gradients on which the car is operated.

It is customary in all automobiles of the gasoline-burning type, where combustion takes place directly in the cylinders, to interpose change-speed gearing which will give two or more ratios of speed between the engine and the road wheels. As it is not possible to reverse the automobile engine utilized in conventional cars, it is necessary to add a set of gears to the gearset to give the wheels a reverse motion when it is desired to back the conveyance.

Many methods of varying the ratio of speed between the engine and traction members have been evolved, but few speed-changing mechanisms have survived. At the present time the majority of automobile makers employ sliding gear transmissions which are almost invariably of the selective type. One or two makes are fitted with simple face-friction gearing and but one maker provides two forward speeds and a reverse motion by using planetary gearing.

Change-Speed Gear Installation.—An important factor in gear-set design is the method of locating it in the frame. There are various systems of gearset mounting in common use. In one, the clutch and gearset form a unit with the

power plant. The advantage of this method of mounting is that it makes a very compact power-generating and speed-changing unit and there will be no liability of lost alignment between the engine and gearset. The gearset is a separate member installed back of the motor just under the front floor boards, and when mounted in this manner it may be attached directly to the main frame side members or to a sub-frame formed by cross members which have been provided for the purpose. In another design the gearset is a unit with the rear axle, and the same argument in favor of mounting applies as when it forms part of the unit power plant except that in this case there is no possibility of lost alignment between the gearset and the driving gears. In the method of installing which is fourth in popularity, the gearset is carried at the front end of the driving shaft housing and is usually attached to the frame in such a manner that it will assist in taking braking and driving torque.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

LABORATORY

LECTURE V

TIRES AND ACCESSORIES

Tires made of rubber are fitted to the wheels of automobiles to take up the vibrations that are too sudden for the springs to absorb.

The wheels of an automobile are smaller in diameter than those of horse-drawn vehicles, principally on account of the high speed at which the automobile travels. If larger, the wheels would have to be built entirely too heavy to sustain the strain. Automobile wheels must be very strong, because of the weight that they have to support and the strain that they are under. They are made of wood or steel.

Wooden wheels are made with a wood felloe, over which fits a steel rim that holds the tire. This is called the artillery type wheel.

Wire wheels are light, and easily repaired, and are becoming very popular.

Mud guards or fenders are always fitted over the wheels, to protect the car and its occupants from the mud thrown by the wheels.

Automobiles are required to carry two lights in front and another called the tail light, in the rear. The rear light is required to avoid accidents. To make driving at night safe, there are usually head lights which burn acetylene gas or electricity.

Electric lights are the most popular. A storage battery supplies the electric current. When the battery runs down, it is recharged from an outside source. If the car is equipped with an electric generator, the battery is kept charged by the generator.

Speedometers show the speed in miles per hour, and are operated by a flexible shaft driven from the front wheel or the transmission shaft.

Odometers show the number of miles traveled either on the trip or during the entire season. Speedometers and odometers are often built in one case, for the sake of compactness. One cable drives them both.

Gradometers show the per cent of grade the car is climbing.

The horn for automobiles is sounded by pressing a rubber bulb, and the tube from the horn bulb to the horn is long enough to have the former at the driver's seat and the latter well forward. Another form of alarm is blown by the pressure of the exhaust from the engine, and it is sounded by pressing on a foot pedal. These horns are called exhaust whistles and the sound is very much like that of a steam whistle. The electric horn is the most popular type.

Bumpers are placed in front of the car and sometimes in the rear. They protect the radiator and lamps.

The wheel base of an automobile is the distance between the rear axle and the front axle. A long wheel base rides easier than a short wheel base. The frame must be sufficiently stiff, however, to prevent sagging from the weight on it. Wheel bases vary from 80 inches on runabouts to 144 inches on larger cars.

The tread, also called the track, is the distance between the wheels measured parallel with the axle. The standard tread is 56 inches, measured where the wheels touch the ground, center to center. The treads of wagons and carriages vary in different parts of the country. In the Southern states they are 60 inches, in the West 48, and in most of the other parts of the country 56 inches. Small light cars are sometimes made with a smaller tread than 56 inches, but only in exceptional cases.

A bruise is an injury to the carcass of a tire which tears the fabric, caused by violent contact with an irregularity. Usually the injury does not show at once. However, the structure of the tire is permanently weakened at the injured spot, and eventually a blowout will occur. Even the most careful and skilled driver cannot avoid bruises altogether. But if your tires are properly inflated and you strike an obstruction, the tire has the resiliency of the air behind it to aid in resisting the impact of the blow, the effect is likely to be less serious.

Experience has taught the careful driver to carry one or more spare tubes, as a cemented roadside repair will not always hold, especially in warm weather, because the heat generated in the tire may loosen the patch. When touring, a spare casing should always be carried. It should be strapped tightly to the tire holder, otherwise it will chafe.

Spare tubes should be kept lightly inflated. This keeps them in good condition and prolongs their life. They should not be stored in a greasy tool-box under any circumstances.

Excessive weight on a casing will break down the fabric in the side walls, and if this practice is persisted in, a blowout is apt to result. When this occurs, the casing is likely to be so badly damaged as to be beyond repair. If roads are very rough and stony or if there are heavy weights in the car, it is better to equip the car with a set of extra-size tires. You can get larger tires which will fit your rims.

Pneumatic tires are designed to carry loads in proportion to their cross-sectional area and diameter. They should never be over-loaded.

The clearance is the distance from the lowest point of the car to the road. For rough roads, a greater clearance is required than for smooth roads, as a high place in the road strikes parts of the machinery that hangs too low. The front axle, which is solid and heavy, is usually curved down in the center, so that it will be the first part of the car to strike a high place, thereby protecting the delicate parts behind it.

The power from the engine is transmitted through the change speed gear and is applied to the propelling of the car by those parts called the drive. There are three types of drives; the double chain drive, requiring a dead rear axle, the single chain drive (seldom used); and the shaft drive, which requires a live rear axle. The double chain drive is seldom used on pleasure cars, but is used quite extensively on trucks. Trucks use chains, because trucks carry heavy loads and must have solid axles. When, as is usual in cars of this type of drive, the engine is in front, the crank shaft is parallel to the sides of the car and therefore at right angles to the rear axle. The power is developed to apply to the wheels and this is done by means of the entire driving gear.

In the double chain drive the power is transmitted from the crank shaft of the engine to the square shaft of the change speed gear by gears, as will be explained. The square shaft carries a bevel gear that meshes with another bevel gear carried on the transmission jack shaft. This jack shaft is at right angles to the square shaft, running in bearings in the gear case. It is held so

rigidly that while it is free to revolve, its bevel gear is always in correct relation to the bevel gear on the square shaft of the change speed gear.

The rear axle jack shaft is in two sections, between the inner ends of which the differential is placed, the differential, of course, being beside the bevel gear that drives the jack shaft. At each end of the jack shaft, outside of the frame, is a sprocket which is in line with a corresponding sprocket on the rear wheel of that side. Over each pair of sprockets passes a chain that transmits the revolutions of the jack shaft to the wheels, which run freely on the ends of the dead axle.

The chain most commonly used for automobiles is called a roller chain. It consists of side pieces in pairs, each pair being secured to the adjoining pairs, by rivets passing from side to side. On these rivets are steel rollers which revolve as they touch the sprockets. These rollers fit the space between the teeth of the sprockets, and as the chain bends around the sprockets the rollers are stationary, while the rivets turn inside of them.

To give the best service, the chain must run true, that is, the sprockets over which it runs must be in line. The links of the chain must fit the teeth, and the sprockets must be exactly circular. If the sprockets are out of line, the chain is forced to bend sideways. If the links do not fit the teeth, there is a grinding that causes rapid wear, and there is danger of the chain jumping off. If the sprockets are not exactly circular, during part of the revolution the chain is slack, and during the remainder stretched tight.

The double chain drive is of advantage on heavy cars. By its use the weight of the car is carried by a solid or dead axle, which is lighter than a divided live axle of the same strength can be. If a solid axle is bent, it can be straightened easily, while it requires an expert mechanic to straighten a bent live axle. The disadvantages of a double chain drive are the difficulty of properly lubricating the chains, the rapid wear in consequence, and the liability of chains to stretch and jump off the sprockets.

Shaft drive for trucks with substantial axles of the live type are not considered superior to the double chain drive. In this type, the square main shaft of the change speed gear is extended to the rear axle, where it ends with a small bevel gear on the differential, that is mounted between the inner ends of the two parts of the live axle and is called the differential driving gear.

The extension of the square main shaft in the transmission or gear set runs to the propeller or driving shaft, and always has one, and often two, universal joints in between the gear box and the drive pinion on the rear end, so that the moving of the rear end as the axle receives the jolts of a rough road does not affect its driving. The bevel gears are contained within a casing or housing that supports the bearings for the inner parts of the axle, and also the end of the driving shaft, so that the bevels are held in the same relation to each other, regardless of the moving of the axle.

The advantages of this type of drive are that all of the moving parts are inclosed and protected from dust, and run in grease or oil. Such a condition is one of practically perfect lubrication. The disadvantages of a divided or split rear axle are the difficulty of keeping the bevel gears in exactly the correct relation to each other, because of the bending or springing of the axle, and the troubles that may come from the general weakness of a live axle.

Bevel gears must be cut more accurately, and meshed more carefully, than spur gears. They are used principally for driving the rear axle. To transmit power without more loss by friction than is necessary, there must be as little play as possible without having the teeth bind. The setting of bevel gears

requires careful adjustment; for if incorrectly meshed they are noisy, and wear rapidly.

Worm driven gears are fast becoming popular for rear axle drives, especially on commercial cars.

The spiral bevel, which is often referred to as the helical gear, is similar to the worm. The worm gear makes a wiping contact and the helical more of a rolling contact. This type of gear is also used to drive ignition systems, etc.

Silent chains are used principally for driving generators, magnetos, and cam shafts.

Radius rods are seldom used, except on commercial cars using the double chain drive. They extend from a point beside the frame at right angles to the jack shaft, thence to the rear axle. They keep the chain at the proper tension and the same distance from sprocket to sprocket, no matter how rough the road. Turnbuckles are provided to adjust them. Many manufacturers, however, have now discarded the radius rod entirely, and the drive is taken directly by the springs.

A torsion rod is used on shaft driven cars. It extends from the change speed gear case to the bevel gear case on the rear axle. In the Hotchkiss drive the torque and drive are taken through the rear springs. The main leaf of each of these is made strong enough for this added duty and the construction does away with torsion tubes, torsion arms, or radius rods. On many cars the propeller shaft housing is made very heavy and acts in place of the torque rods.

If it were not for the torsion rod, the revolving of the bevel gears would tend to revolve the rear axle housing around the axle, instead of revolving the axle inside of the housing. While the construction of the rear axle could, of course, prevent this, there would be considerable play in the course of time, and the driving shaft might be strained and sprung out of line. The torsion rod receives this strain, and protects the driving shaft. It resists the torque of the rear axle when power or brakes are applied.

Drive Reduction.—In all but racing cars, the speed of the crank shaft is reduced so that the rear wheels turn once while the crank shaft revolves from three to four or four and one-half times with the high speed gear engaged. On shaft driven cars, the reduction is made at the bevel gears. The bevel on the axle is given as many more teeth than the pinion on the driving shaft as is necessary for the reduction that is required. In the worm drive, reduction is governed by the angularity of the teeth and not by the ratio. In other words, the size of the worm may be changed without changing the speed. The angularity, of course, has to be the same in both cases. To make it clear, how the speed reduction is brought about in the worm drive, imagine the screw thread on a vise shaft which draws the jaws together. If that thread is coarse, the jaws move towards each other rapidly and it takes some power to move it; if there are quite a number of threads to the inch, the jaws move more slowly; but the vise is easier to turn.

The reduction on side chain cars is sometimes made at the bevel driving the jack, but usually at the sprockets. Racing cars, or high powered touring cars for use over good roads, apply this reduction to the direct drive in the differential, but by the use of gears in the change speed gear case one may bring the speed of the wheels to the speed of the crank shaft, or even more.

When the gear ratio of a car is spoken of, it is this reduction in the differential that is referred to. A car which has a gear ratio of 3½ is one in which the crank shaft makes 3½ revolutions to one revolution of the wheels when in high gear.

It is not practical to steer an automobile as a horse-drawn vehicle is steered, for the reason that the axle has to be very heavy to support the weight; and besides, it would be so hard to swing the car that steering would be difficult. Another reason is that the body would have to be raised up high enough for wheels to go under it. A fixed front axle is always used on automobiles. The pivot on which the front wheels swing must be as close to the hubs of the wheel as possible; for the closer they are, the less leverage there is to overcome, and the easier it is to steer. When a wagon or automobile turns a corner, it moves in the arc of a circle. The front axle of an automobile is fixed and cannot turn, and therefore, only its pivoted ends point to the center of the circle. When running straight ahead, the front wheels of an automobile are square with the axle. When turning, the front wheels are not square with the axle, but are at an angle to it. Because each wheel is square with its axle end, and both axle ends point to the center of the circle, each wheel is square, or perpendicular to a radius of the circle. If both were perpendicular to the same radius as they are not, the wheels would be parallel with each other. Thus while the front wheels of a horse-drawn vehicle are always parallel to each other, the front wheels of an automibile turning a corner are not parallel to each other.

The steering mechanism must be so arranged that the front wheels are parellel when the car is running straight ahead.

Each of the pivoted axle ends, which are called steering knuckles, has a steering arm projecting from it. The ends of these two arms are connected by a rod called a tie rod. When the drag link is moved endways, both wheels move with it. The two steering arms are not parallel, but incline a little toward each other. If they were parallel, the two wheels would be parallel, no matter how the drag link was moved. As they are not parallel, moving the drag links moves one of the wheels through a greater angle than the other, depending on the direction the drag link is moved.

The old style of steering arrangement was a lever and rod running from the the driver's seat to the steering knuckle. This old style arrangement was unreliable. In striking stones or ruts in the road the wheels were thrown from side to side, and the driver was obliged to grasp the steering lever firmly to keep the car straight. A device must be used that swings the front wheels when the steering wheel is turned, but that keeps the front wheels steady, and prevents their moving the steering wheel. This is called an irreversible steering gear, and while it is made in many ways, the chief types are the worm and sector, and the screw and nut or worm and nut.

The worm and sector type consists of a worm, which is attached to the lower end of the rod moved by the steering wheel. Meshing with the worm is a sector wheel, so that turning the steering wheel turns the worm and moves the sector wheel. Attached to the sector is an arm, which is connected to the drag link by the connecting arm or rod. The end of the arm is ball-shaped and fits in a socket on the end of the rod; thus the fit is always tight, whatever the angle between the arm and the connecting rod may be. The socket is often movable, with strong springs on each side to hold the parts together and to take up some of the shocks of the road.

The worm and sector are contained inside a metal case to protect them from dust, and to hold the grease in which they are packed.

The worm and nut type steering gear has a nut, through which a worm screw gear passes. Instead of a sector the nut is used. The screw is fastened to the steering rod. Turning the steering rod moves the nut up and down. One arm of the lever fits in a groove on the outside of the nut, and the other

end is connected to the drag link by a connecting rod. Steering gears are usually built so that wear can be taken up, as looseness of the parts makes the steering uncertain.

The breaking of any part of the steering connections is more likely to cause a wreck than the breaking of any other part of the car. The parts must be kept tight enough to prevent play, but must not be so tight as to make steering hard. All parts must be kept lubricated, and the connecting rod, drag link and knuckle joint are usually packed in grease and protected from dust by leather boots which buckle over them.

Brakes

Brakes which act on the rear wheels are either of the contracting or expanding band type or the expanding shoe type.

Expanding brakes are known as double internal brakes. A steel brake drum is fastened securely to the wheel. Both bands expand and put pressure on the inside of the drum. The outside band, or the one next the wheel, is the emergency brake and is operated by a hand lever. The other, the service brake, is under the control of the driver through the medium of the foot pedal. The brake bands are carried by brake flanges near the ends of the rear axle housing. The two sets are entirely independent of each other. Another type of internal expanding band brake that uses two brake drums on each wheel, is similar in action to the above. In this case the smaller band is used for the emergency. There are two bands working on the same drum. One set contracts around the outside of the drum and the other set expands against the inner circumference. The outer band constitutes the service or foot brake and the inner band the emergency brake.

All bands, either contracting or expanding, are faced on the rubbing side with an interwoven wire asbestos composition that is capable of standing a great amount of wear and is not easily burned out. Some types that use the expanding shoe have a cast-iron shoe that is pressed against the inside of the steel drum on the wheel.

There is a typical mechanism for operating the expanding shoes or drums and the emergency band, while the service brake is in running position.

Motor Truck Company Drivers' Course

SHOP WORK

EXERCISE I

IGNITION AND LIGHTING

(*a*) Bad battery.

In the shop the mechanic will find the repair kit in the electric battery repair tool crib listed in a neat and concise form.

To repair a bad or damaged battery one should be able to understand clearly the proper working of the type of battery he is repairing.

There are several causes for damaged or bad batteries: if the battery was dropped and cracked or broken in a smash up it may be re-cemented; if the insulating material is cracked open or if the box is cracked it may be repaired easily. To tear down a storage battery one must observe the following rules:

First.—Remove all vent plugs and washers.

Second.—Centerpunch both top connectors, both of which are to be repaired; then drill ¾ inch into top connector, with a ⅝ inch diameter drill. Now pull over connector with pliers.

Third.—Apply gas flame or blow-torch flame to the top of the battery long enough to soften the sealing compound under the top cover. With a heated putty knife, cut out the sealing compound around the edge of top cover.

Fourth.—Insert a putty knife, or any thin, broad pointed tool, heated in flame, along inside of top cover, separating it from the sealing compound. Then with putty knife, pry the top cover up the sides and off of the terminal posts.

Fifth.—Then, with heated knife, remove all sealing compound from inner cover.

Sixth.—Play the flame upon the inner cover until it becomes soft and pliable; then take hold of both terminal posts of one cell and remove the elements from the jar, slowly; then lift the inner cover from the terminal post.

Seventh.—Now separate positive and negative elements, by pulling them part sideways. Destroy old separators.

Eighth.—To remove a leaky jar, first empty the electrolyte from the jar, and then play the flame on the inside of the jar until the compound surrounding it is soft and plastic; then with the aid of two pliers remove it from the crate, slowly, lifting evenly.

Ninth.—To put in a new jar, in place of the leaky one, heat it thoroughly, in a pail of hot water and force in gently.

Tenth.—In re-assembling the battery, first assemble the positive and negative elements, pushing them together sideways; then turn them on the side and with both held down in place, insert new separator, being very careful to have the grooved side of the separators next to each side of each positive plate. Also be careful to have the separators extend beyond the plates on each side, so there will be no chance of the plates short circuiting.

Eleventh.—Heat inner cover with flame; then place same in terminal posts; then take hold of both terminal posts and slowly lower the elements into the jar.

Twelfth.—With expansion chamber in place on the inner cover, pour the melted sealing compound upon the inner cover, until it reaches the level of the hole in the top of the expansion chamber, so that when the top cover is replaced, it will squeeze the sealing compound off the top of expansion chamber.

Thirteenth.—Now soften top cover with flame and replace on terminal posts until it rests on top of expansion chamber. Then place a weight on top cover until sealing compound cools.

Fourteenth.—Pour sealing compound around edge of the top cover, until it reaches the top of top cover. Then when the sealing compound has cooled, take a knife and scoop extra sealing compound off of top cover, making a smooth surface over the top of the battery.

Fifteenth.—In burning the top connector to terminal posts proceed as follows: scrape the hole of the top connector until the surface is bright and clean; scrape terminal post until top and edge are bright and clean. Now scrape a piece of lead, preferably a small bar, bright and clean; then apply hydrogen gas flame, mixed with air under pressure, to the top connector and terminal post assembled, at the same time heating lead bar. When top connector and terminal post begin to melt it, thus making a firm burned connection, fill rest of hole-space with melted lead and smooth off even with top of top connector.

(*b*) Grounded wires.

Grounded wires can be detected by the use of a bell ringer or a small hand magnet. The mechanic should be thoroughly acquainted with the system that he is working on. The wiring diagram of all standard U. S. Army vehicles will be found in stock room.

In repairing grounds one should be careful to tape the wires in a neat manner.

(*c*) Timer not making contact.

A varying speed motor may result from the timer not making contact.

By removing distributor or distributing device one will plainly see the causes of not making contact. The distributor may be cleaned with cloth dampened with gasoline. The brush may be worn; if so, it may be trimmed up, cleaned or if too far gone, a new brush should be fitted. The distributing segments, if rough or coarse, may be smoothed up with a piece of fine emery cloth on a small block of wood.

(*d*) Coil vibrator poor.

An uneven running motor may be caused by a coil vibrator in poor condition. If the coil is tested and found to be all right, the vibrator should next be tested. A very fine flat file should be used to clean and even up the points. If it is found that the points are gone, new points can be had and put in place of the old ones.

(*e*) Spark plugs defective.

Defective plugs should be repaired by inserting new porcelains.

The mechanic should know how to test for a defective spark plug. If the treads on the shell are stripped a new shell is the best method of repairing the plug.

(*f*) Wet coil.

If a coil is tested and found to be wet, it should be put in a dry place and dried by heat from a radiator or some heating device. Great care must be taken to keep away from flame or too high a temperature. To dry a wet coil, the coil box should be removed and the coil held up by a suitable fixture so as not to damage the windings.

(*g*) Adjusting the charging rate passed by regulator.

On the standard "B" truck the current output of the generator starts charging at low speed and the output increases with speed until a maximum output is reached, when it starts to decrease. The maximum output as indicated by the connector on the dash should be 10 to 13 amperes, with all lights off. To adjust output, loosen three screws in the small circular plate on the commutator end of the generator. Do not screw them all the way out. To raise the output, rotate the plate slightly in a clockwise direction; to lower the output, rotate the plate in a counter clockwise direction.

Motor Truck Company Drivers' Course

SHOP WORK

EXERCISE II

LOCATION OF TROUBLE IN FUEL SYSTEM

(*a*) Water in gasoline.

If water is found in the gasoline it may be strained out by use of a piece of chamois or a very fine strainer. Care must be taken to make sure that all water is removed from the gasoline.

(*b*) Clogged piping or strainer.

Clogged piping or clogged strainers should be thoroughly cleaned with a swab on the end of a wire, and run through the systems. Dents, etc., should be taken out or a piece of pipe inverted or a pipe joint made in the dented place.

(*c*) Vacuum tank defective.

When the vacuum tank becomes defective, the first part suspected to be out of working order is the float. This may be tested and repaired with a thin covering of solder. The piping connections must be kept tight to prevent air leaks.

The different arms and pins become worn or broken and they can be replaced or repaired easily.

(*d*) Leak in gasoline line.

A leak in the gasoline line can be repaired easily by the ordinary mechanic although care must be taken not to allow solder on the inside of the pipes. Breaks, dents, etc., may be repaired as described in paragraph (*b*). Couplings, etc., may be riveted together and a fair job can be done by the ordinary mechanic.

(*e*) Poor float in carburetor.

If the float is constructed of cork, it may be laid out on a shelf to dry, then scraped and a thin coating of shellac put on and left to dry. If float is of metal it can be repaired with a thin coat of solder. Care should be taken not to unbalance the float as this will cause considerable trouble.

(*f*) Clogged needle valve.

Dirt may be easily removed from under a needle valve. Notice should be taken of the condition of the needle valve. If the needle valve is rough or dull it should be ground in, care being taken to remove all particles of grinding compound.

(*g*) Sticking auxiliary valve.

The auxiliary air valve rides on a bushing in the center of the chamber. This bushing becomes rusty and gritty. By draining it thoroughly and applying a few drops of oil, it will work satisfactorily.

(*h*) Leak in intake manifold.

Leaky intake manifolds can be repaired by either renewing gasket or smoothing up and fitting the manifold tight.

(*i*) Cleaning carburetor.

The carburetor must be completely taken apart to insure proper cleaning. Each part must be wiped clean with a cloth and dampened with gasoline. When re-assembling parts one must take care that no foreign matter collects or sticks in the carburetor.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

SHOP WORK

EXERCISE III

STEERING GEAR AND BRAKES

(*a*) Adjustment of steering gear.

For play in the steering apparatus one should thoroughly understand the design and operation of the type of steering apparatus he is working on. There are two shims where the steering column bolts on the steering gear housing which provide a means of taking up end play of the worm shaft. Do not under any condition tighten up the steering gear adjustment to a point where the wheel turns hard. A tremendous pressure can be placed upon the steering gear by too close an adjustment, which will bind the working parts, cause excessive wear, and make steering difficult. The ball-thrust bearing is especially apt to be seriously damaged or even broken if the steering gear is adjusted too tightly.

(*b*) Alignment of front wheels.

The front wheels may be thrown out of alignment by striking some heavy obstruction in the road. This not only makes steering more difficult but is also hard on tires and bearings and the wheel itself. The front wheels should "Toe in" slightly. A difference of ⅛ to ⅜ inches between the front and rear of the rims when the wheels are straight ahead is correct. Re-bushing king bolts and steering knuckles: Old bushings can be driven out by a piece of stock a few thousandths smaller than the bushing itself. A reamer should be used so that no mark will interfere when inserting the new bushing. When inserting the new bushing a piece of stock, the same size as the bushing should be used to drive it in.

(*c*) Tightening brakes.

It is very important when brake adjustments are made to take care not to get them so tight that they will drag, as a dragging brake not only gets hot and wears out rapidly but also absorbs considerable power.

With both wheels jacked up and both brakes completely off adjust the brake shoe so it has a clearance of 0.010 inch all the way around the brake drum, then adjust the toggles so that when the brake is pulled up tight the pin connecting both toggles to the lever will lack 2 inches of coming in the line of the pins at the brake shoe ends of the toggles. Set the lever to which pull rod attaches about 15° back of center, so that when brake is applied it will be pulled up straight.

(*d*) Re-lining Brakes.

When re-lining brakes the proper lining should be riveted on in a neat manner. Place the lining over the band and mark off the riveted holes, then punch same with a belt punch or some suitable device. The rivets must be finished off in a very neat manner, leaving no rough particles to tear or cut into the brake drum.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

SHOP WORK

EXERCISE IV

TROUBLE SHOOTING

I. Power Plant Troubles.
- (*a*) Mechanical parts of engine.
- (*b*) Carbureting and gasoline system.
- (*c*) Ignition.
- (*d*) Lubricating and cooling.
- (*e*) Starting and lighting.

II. Transmission Troubles.
- (*a*) Clutch.
- (*b*) Change gears.
- (*c*) Differential.
- (*d*) Rear axle.

III. Chassis Troubles.
- (*a*) Wheel hubs.
- (*b*) Steering gear.
- (*c*) Brakes.
- (*d*) Springs.
- (*e*) Tires.

(1) Engine Fails to Start.
- (*a*) Poor compression.
- (*b*) Engine cylinder flooded.
- (*c*) Carburetor adjustment not right.
- (*d*) Water in gasoline.
- (*e*) Carburetor frozen.
- (*f*) Out of gasoline.
- (*g*) Engine too cold.
- (*h*) Ignition switch off.
- (*i*) Foul or broken plugs.
- (*j*) Weak batteries or magneto.
- (*k*) Vibrators not properly adjusted.
- (*l*) Wiring system out of order.

(2) Engine Misses at Low Speeds.
- (*a*) Poor compression.
- (*b*) Mixture too lean or too rich.
- (*c*) Spark plug gap too wide.
- (*d*) Spark plug cable not connected or short circuited.
- (*e*) Dirty interrupter.
- (*f*) Dirty or defective spark plug.
- (*g*) Vibrator not properly adjusted.

(3) Engine Misses at High Speeds Only.
- (*a*) Carburetor not set for this speed.

(*b*) Bad spark plug.
(*c*) Weak valve spring.
(*d*) Timer contact imperfect.
(*e*) Vibrator points dirty or burned.

(4) Engine Misses at All Speeds.

(*a*) Carburetor not properly adjusted.
(*b*) Dirty or broken plug.
(*c*) Spark plug gap not right.
(*d*) Poor compression.
(*e*) Loose or broken terminals.
(*f*) Weak batteries or magneto.
(*g*) Defective wiring.
(*h*) Coil not properly adjusted.
(*i*) Gasoline feed stopped up.
(*j*) Water in gasoline.
(*k*) Poor circulation.
(*l*) Excessive lubrication.

(5) Engine Overheats.

(*a*) Lack of proper circulation.
(*b*) Lack of proper lubrication.
(*c*) Slipping fan belt or bent fan blades.
(*d*) Too rich a mixture.
(*e*) A weak mixture.
(*f*) Running with spark retarded.
(*g*) Carbon deposit in cylinders.

(6) Engine Stops.

(*a*) Gasoline tank empty.
(*b*) Water in gasoline.
(*c*) Carburetor flooded.
(*d*) Lack of pressure on gasoline tank.
(*e*) Overheating due to poor circulation or lack of lubrication.
(*f*) Short-circuiting of wires or terminals.
(*g*) Disconnected or broken wires.
(*h*) Wet batteries or magneto.

(7) Engine Knocks.

(*a*) Carbon deposits in cylinder and on piston heads.
(*b*) Spark too far advanced.
(*c*) Running motor slow when pulling heavy load on direct drive.
(*d*) Faulty lubrication.
(*e*) Engine overheated.
(*f*) Loose connecting rod bearings.
(*g*) Loose piston.

(8) Engine Will Not Stop.

(*a*) Short circuit in switch.
(*b*) Magneto ground may be disconnected.
(*c*) Overheating and carbon deposits.

(9) Lack of Power.

(*a*) Poor compression.
(*b*) Too weak or too rich a mixture.
(*c*) Weak spark.

(*d*) Lack of lubrication.
(*e*) Lack of cooling water.
(*f*) Lack of gasoline.
(*g*) Dragging brakes.
(*h*) Slipping clutch.
(*i*) Flat tires.
(*j*) Choked muffler causing back pressure.

(10) Back-firing Through Carburetor.

(*a*) Improper needle valve adjustment.
(*b*) Dirt in gasoline passage or nozzle.
(*c*) Inlet valves holding open.
(*d*) Excessive temperature of the hot water jacket of the carburetor, especially in hot weather. This can be remedied by shutting off the water from the carburetor jacket and cutting off the hot air supply.
(*e*) Spark retarded too far.

(11) Firing in Muffler.

(*a*) Weak mixture, slow burning exhaust, igniting unburned charge from previous "miss."
(*b*) Valves out of time.
(*c*) Too rich a gasoline mixture.
(*d*) Occasional missing of a cylinder.

Engine Fails to Start.

Poor Compression.—Poor compression is one of the common causes for lack of power. Unless the compression pressure is high enough, the explosion will be lacking in force and the engine will be weak. The engine can be turned by hand, with the ignition off, throttle open, and the compression noted in each cylinder, or a more accurate way is to remove the spark plug and screw in a small pressure gauge, which should show from 60 to 80 lbs. at the end of the compression stroke, depending on the make of the engine. Loss of compression is commonly due to leaky or improperly seated valves, or to leaky joints. Leaky thread joints, valve caps and cracks in cylinder are common causes for loss of compression. These can be detected by a hissing sound or, if the suspected leak is covered with gasoline or oil, the leak will show itself by air bubbling through the oil. If the trouble cannot be located in this manner, attention should be given to the valves.

As a rule, the intake valve requires less attention than the exhaust valve, because the former comes in contact with the cool fresh fuel charges, whereas the latter is apt to become fouled and burnt by the hot and dirty exhaust gases. A frequent cause of leaky valves is carbon deposit on the valve seats. These deposits prevent the proper seating of the valve. The remedy is to clean and grind the valves.

Engine Cylinder Flooded.—If the engine has been cranked for some little time and too much gasoline has been sucked into the cylinders, the cylinders become flooded with almost pure gasoline which condenses in the cold cylinders. This charge will not explode. The remedy is to open the priming cocks and crank the engine until the overrich mixture has been expelled or diluted with air. The priming cocks can then be closed and the engine will usually start. Flooding of the engine can also be caused by priming the cylinders with too much gasoline. It sometimes happens that a flooded engine can be started without difficulty after standing for several hours. The excess gasoline has evaporated in the meantime.

Carburetor Adjustment Not Right.—Improper mixture is the common source of carburetor trouble. The mixture is either too rich, that is, too much gasoline in proportion to the air, or too weak, that is, too much air in proportion to the gasoline.

Water in Gasoline.—It sometimes happens that the carburetor becomes loaded with water, due to the fact that the water can neither evaporate nor get out. This water prevents the gasoline from getting in. The water should be drained from the carburetor drain cock.

Carburetor Frozen.—If there is water in the gasoline, this water may be frozen in the carburetor. The water, being heavier than the gasoline, sinks to the bottom where it may freeze in cold weather. To remedy this trouble apply hot cloths to the parts affected. Never use a torch or flame of any sort around the carburetor.

Out of Gasoline.—It sometimes happens that if a pressure gasoline system is used, the pressure becomes too low to force the gasoline from the main tank to the auxiliary tank. This causes a lack of fuel at the carburetor. A hand pump on the dash is usually furnished for increasing this air pressure in the tank.

If the car is equipped with a gravity feed system, the gasoline may fail to run to the carburetor when ascending a steep hill. It sometimes becomes necessary to back the car uphill, in which case the gasoline will run to the carburetor without difficulty.

Engine Too Cold.—In cold weather, when the engine is stiff and the gasoline is hard to evaporate, it is necessary to inject a little warm or high test gasoline into each cylinder through the priming cocks. The carburetor may also be heated by the application of warm cloths. The priming gasoline can be heated to advantage by placing a bottle of it in a pan of hot water.

Ignition Switch Off.—Open circuit.

Foul or Broken Plugs.—A defective plug may be broken, oil soaked, carbonized, or the air gap between terminals too much or too little. If the plug is broken, it must be replaced by a new plug. A plug with a loose center electrode may sometimes be repaired. If carbonized or sooted up, the plug may readily be cleaned with a stiff brush and gasoline. Do not scrape with a knife, as it merely rubs the carbon into the surface of the porcelain.

The gap between plug terminals should be between 1/40 and 1/32 in. It should not be more nor less than this for efficient ignition. A smooth disc is a good gauge to use for setting this gap.

Weak Batteries or Magneto.—Weak or exhausted batteries are a common source of trouble. If the batteries are suspected, they should be tested with a small "ammeter." If any one of the dry cells shows less than 6 amp., it should be taken out and replaced with a new one. One weak cell will greatly interfere with the operation of the others in the set. Occasionally a weak dry cell can be livened up temporarily by boring a small hole through the top and pouring in a small quantity of water, or better still, of vinegar. The effect is, however, only a temporary one.

Dry batteries should always be kept perfectly dry. If they become wet on the outside, there is a tendency for the battery to be short-circuited and exhaust itself. Especially is this true if water spills on the top of the battery between the terminals.

If the storage battery appears dead or shows lack of energy, it may be due to one of the following causes of trouble: (a) discharged; (b) electrolyte in the jar too low; (c) specific gravity of electrolyte too low; or (d) plates sulphated.

These troubles are fully treated in the chapter on starting and lighting under the heading of Storage Batteries.

If the ignition trouble has been located in the magneto side of the system and the plugs and wiring system have been found in good working order, attention should be turned to the magneto itself. The distributor plate should be thoroughly cleaned with gasoline to remove any foreign matter which may have collected after considerable use. After attending to this, it should be determined whether or not the magneto is generating current. This can be done by disconnecting the magneto cables and watching the safety spark gap while cranking the engine. If no spark appears there, the trouble is in the magneto itself.

The contact points may be pitted or burned. They should be filed until they meet each other squarely. Be sure that the adjustment is properly made.

The carbon or collector brushes may be dirty or worn. They should be cleaned, or if badly worn, replaced with new brushes.

It occasionally happens that the magnets become weak or demagnetized. They may possibly be placed in the magneto in the wrong position. If weak or demagnetized, they should be remagnetized before being replaced. Care should be exercised in getting the like poles of the magnets together on the same side of the magneto. Most magnets are markel with an "N" indicating the north pole.

Vibrators Not Properly Adjusted.—A frequent cause of no current at the plug is coil trouble, especially where a vibrating coil is used for each cylinder. The vibrator points become pitted, out of line and burned, making good contact impossible. The tension on the vibrator spring becomes changed, permitting the coil to consume too much or too little current.

Burned or pitted points should be filed flat with a thin smooth file, or hammered flat with a small hammer. In either case the points should be so shaped as to meet each other squarely.

If it becomes necessary to adjust the tension on the vibrators, the tension should be entirely taken off and gradually increased until the engine runs satisfactorily without missing. It is very important to have all the units adjusted alike. This can be easily done after a little experience. The most accurate method of coil adjustment is with a coil current indicator by which the amount of current consumed is measured. Coils are built to consume about ½ amp., and the tension should be adjusted so that the current consumption of each coil is not greater than this amount.

Wiring System Out of Order.—If there is no current at the plug, the wiring system should be examined carefully for dirty and loose terminals, broken connections, and oil soaked and wet wiring. If the insulation has been worn off, the current is liable to be short circuited or grounded through the engine or frame of the car. Defective or poor contacts at switches may also be the cause of no current at the plugs.

If no current is obtained in the secondary winding of a coil, when the vibrator is working as it should, the trouble is probably due to a broken wire inside of the coil. It sometimes happens that the binding post wires become loose from the post just inside of the coil. If only a slight spark can be obtained, the insulation on the inside wire may be broken down, thus causing a short circuit of the current. Obviously there is no remedy but to replace the coil.

Trouble in the timer or commutator usually comes from oil, water and dirt which have found its way inside of the housing, causing a short circuit. This

foreign matter should be cleaned out of the timer in order to have it give good service. After a time, the contact points in the timer become worn and loose. New points should be put in and all loose parts tightened. If the lost motion becomes too great, it may be necessary to supply a new timer.

Engine Misses At Low Speeds

Poor Compression.—Poor compression is one of the common causes for lack of power. Unless the compression pressure is high enough, the explosion will be lacking in force and the engine will be weak. The engine can be turned by hand, with the ignition off, throttle open, and the compression noted in each cylinder, or a more accurate way is to remove the spark plug and screw in a small pressure gauge, which should show from 60 to 80 lbs. at the end of the compression stroke, depending on the make of the engine. Loss of compression is commonly due to leaky or improperly seated valves, or to leaky joints. Leaky thread joints, valve caps and cracks in cylinders are common causes for loss of compression. These can be detected by a hissing sound or, if the suspected leak is covered with gasoline or oil, the leak will show itself by a bubbling through the oil. If the trouble cannot be located in this manner attention should be given to the valve.

As a rule, the intake valve requires less attention than the exhaust valve, because the former comes into contact with the cool fresh fuel charges, whereas the latter is apt to became fouled and burnt by the hot dirty exhaust gases. A frequent cause of leaky valves is carbon deposit on the valve seats. These deposits prevent the proper seating of the valve. The remedy is to clean and grind the valves.

Mixture Too Lean or Too Rich.—A rich mixture shows itself by black smoke coming from the muffler, and by overheating and missing of the engine. Not only is fuel wasted, but the cylinders become fouled and carbonized. A mixture too rich at slow speeds should be corrected by cutting down on the gasoline, and at high speeds by increasing the auxiliary air. An auxiliary air spring which sticks, a restricted air opening, or a flooded carburetor will cause an overrich mixture.

A weak mixture can be detected by back-firing through the carburetor and by occasional muffler explosions. A weak mixture, being a slow burning mixture, is still burning when the intake valve opens for the following charge. This permits the flame to shoot back through the manifold into the carburetor. A weak mixture should not be confused with an improperly timed intake valve which opens before the burning charge has been exhausted. If the intake valve has a weak spring which does not close the valve properly, it may permit back-firing through the carburetor. The explosions caused by the valve trouble are usually more violent than a back-fire due to weak mixture. A weak mixture at low speeds is caused generally by too little gasoline and at high speeds by too much auxiliary air and the carburetor should be adjusted accordingly.

An air leak in the manifold connections will dilute the mixture with air and cause a weak mixture and back-firing. These leaks should be remedied before the carburetor adjustments are changed.

A stuck or bent or obstructed gasoline needle valve may cause a weak mixture by shutting off the supply of gasoline. The remedy is obvious.

Spark Plug Gap Too Wide.—A defective plug may be broken, oil soaked, carbonized, or the air gap between terminals too much or too little. If the plug is broken, it usually must be replaced by a new plug. A plug with a loose center electrode may sometimes be repaired. If carbonized or sooted up, the

plug may readily be cleaned with a stiff brush and gasoline. Do not scrape with a knife, as it merely rubs the carbon into the surface of the porcelain.

The gap between plug terminals should be between 1/40 and 1/32 in. It should not be more or less than this amount for efficient ignition. A smooth dime is a good gauge to use for setting this gap.

Spark Plug Cable Not Connected or Short Circuited.—If there is no current at the plug, the wiring system should be examined carefully for dirty and loose terminals, broken connections, and oil soaked and wet wiring. If the insulation has been worn off, the current is liable to be short-circuited or grounded through the engine or frame of the car. Defective or poor contacts at switches may also be the cause of no current at the plugs.

Dirty Interrupter.—Trouble in the timer or commutator usually comes from oil, water, and dirt which has found its way inside of the housing, causing a short circuit. This foreign matter should be cleaned out of the timer in order to have it give good service. After a time, the contact points in the timer become worn and loose. New points should be put in and all loose parts tightened. If the lost motion becomes too great, it may be necessary to supply a new timer.

Dirty or Defective Spark Plug.—A defective plug may be broken, oil soaked, carbonized, or the air gap between terminals too much or too little. If the plug is broken, it must be replaced by a new plug. A plug with a loose center electrode may sometimes be repaired. If carbonized or sooted up, the plug may readily be cleaned with a stiff brush and gasoline. Do not scrape with a knife, as it merely rubs the carbon into the surface of the porcelain.

The gap between plug terminals should be between 1/40 and 1/32 in. It should not be more or less than this amount for efficient ignition. A smooth dime is a good gauge to use for setting this gap.

Vibrator Not Properly Adjusted.—A frequent cause of no current at the plug is coil trouble, especially where a vibrating coil is used for each cylinder. The vibrator points become pitted, out of line, and burned, making good contact impossible. The tension on the vibrator spring becomes changed, permitting the coil to consume too much or too little current.

Burned of pitted points should be filed flat with a thin smooth file, or hammered flat with a small hammer. In either case the points should be so shaped as to meet each other squarely.

If it becomes necessary to adjust the tension on the vibrators, the tension should be entirely taken off and gradually increased until the engine runs satisfactorily without missing. It is very important to have all the units adjusted alike. This can be easily done after a little experience. The most accurate method of coil adjustment is with a coil current indicator by which the amount of current consumed is measured. Coils are built to consume about ½ amp. and the tension should be adjusted so that the current consumption of each coil is not much greater than this amount.

Engine Misses At High Speeds Only

Carburetor Not Set for This Speed.—A rich mixture shows itself by black smoke coming from the muffler, and by overheating and missing of the engine. Not only is fuel wasted, but the cylinders become fouled and carbonized. A mixture too rich at slow speeds should be corrected by cutting down on the gasoline, and at high speeds by increasing the auxiliary air. An auxiliary spring which sticks, a restricted air opening, or a flooded carburetor will cause an overrich mixture.

A weak mixture can be detected by back-firing through the carburetor and by occasional muffler explosions. A weak mixture, being a slow burning mixture, is still burning when the intake valve opens for the following charge. This permits the flame to shoot back through the manifold into the carburetor. A weak mixture should not be confused with an improperly timed intake valve which opens before the burning charge has been exhausted. If the intake valve has a weak spring which does not close the valve properly, it may permit back-firing through the carburetor. The explosions caused by the valve trouble are usually more violent than a back-fire due to weak mixture. A weak mixture at low speeds is caused generally by too little gasoline and at high speeds by too much auxiliary air and the carburetor should be adjusted accordingly.

An air leak in the manifold connections will dilute the mixture with air and cause a weak mixture and back-firing. These leaks should be remedied before the carburetor adjustments are changed.

A stuck or bent or obstructed gasoline needle valve may cause a weak mixture by shutting off the supply of gasoline. The remedy is obvious.

Bad Spark Plug.—A defective plug may be broken, oil soaked, carbonized, or the air gap between terminals too much or too little. If the plug is broken, it must be replaced by a new plug. A plug with a loose center electrode may sometimes be repaired. If carbonized or sooted up, the plug may readily be cleaned with a stiff brush and gasoline. Do not scrape with a knife, as it merely rubs the carbon into the surface of the porcelain.

The gap between plug terminals should be between 1/40 and 1/32 in. It should not be more nor less than this amount for efficient ignition. A smooth dime is a good gauge to use for setting this gap.

Weak Valve Spring.—A weak mixture can be detected by back-firing through the carburetor and by occasional muffler explosions. A weak mixture, being a slow burning mixture, is still burning when the intake valve opens for the following charge. This permits the flame to shoot back through the manifold into the carburetor. A weak mixture should not be confused with an improperly timed valve which opens before the burning charge has been exhausted. If the intake valve has a weak spring which does not close the valve properly, it may permit back-firing through the carburetor. The explosions caused by the valve trouble are usually more violent than a back-fire due to weak mixture. A weak mixture at low speeds is caused generally by too little gasoline and at high speeds by too much auxiliary air and the carburetor should be adjusted accordingly.

An air leak in the manifold connections will dilute the mixture with air and cause a weak mixture and back-firing. These leaks should be remedied before the carburetor adjustments are changed.

A stuck or bent obstructed gasoline needle valve may cause a weak mixture by shutting off the supply of gasoline. The remedy is obvious.

Timer Contact Imperfect.—Trouble in the timer or commutator usually comes from oil, water, and dirt which has found its way inside of the housing, causing a short circuit. This foreign matter should be cleaned out of the timer in order to have it give good service. After a time, the contact points in the timer become worn and loose. New points should be put in and all loose parts tightened. If the lost motion becomes too great, it may be necessary to supply a new timer.

Vibrator Points Dirty or Burned.—A frequent cause of no current at the plug is coil trouble, especially where a vibrating coil is used for each cylinder. The vibrator points become pitted, out of line, and burned, making good con-

tact impossible. The tension on the vibrator spring becomes changed, permitting the coil to consume too much or too little current.

Burned or pitted points should be filed flat with a thin smooth file, or hammered flat with a small hammer. In either case the points should be so shaped as to meet each other squarely.

If it becomes necessary to adjust the tension on the vibrators, the tension should be entirely taken off and gradually increased until the engine runs satisfactorily without missing. It is very important to have all the units adjusted alike. This can easily be done after a little experience. The most accurate method of coil adjustment is with a coil current indicator by which the amount of current consumed is measured. Coils are built to consume about ½ amp. and the tension should be adjusted so that the current consumption of each coil is not much greater than the amount.

Engine Misses At All Speeds

Carburetor Not Properly Adjusted.—A rich mixture shows itself by black smoke coming from the muffler, and by overheating and missing of the engine. Not only is fuel wasted, but the cylinders become fouled and carbonized. A mixture too rich at slow speeds should be corrected by cutting down on the gasoline, and at high speeds by increasing the auxiliary air. An auxiliary air spring which sticks, a restricted air opening or a flooded carburetor will cause an overrich mixture.

A weak mixture can be detected by back-firing through the carburetor and by occasional muffler explosions. A weak mixture, being a slow burning mixture, is still burning when the intake valve opens for the following charge. This permits the flame to shoot back through the manifold into the carburetor. A weak mixture should not be confused with an improperly timed intake valve which opens before the burning charge has been exhausted. If the intake valve has a weak spring which does not close the valve properly, it may permit back-firing through the carburetor. The explosions caused by the valve trouble are usually more violent than a back-fire due to weak mixture. A weak mixture at low speeds is caused generally by too little gasoline and at high speeds by too much auxiliary air and the carburetor should be adjusted accordingly.

An air leak in the manifold connections will dilute the mixture with air and cause a weak mixture and back-firing. These leaks should be remedied before the carburetor adjustments are changed.

A stuck or bent or obstructed gasoline needle valve may cause a weak mixture by shutting off the supply of gasoline. The remedy is obvious.

Dirty or Broken Plug.—A defective plug may be broken, oil soaked, carbonized, or the air gap between terminals too much or too little. If the plug is broken, it must be replaced by a new plug. A plug with a loose center electrode may sometimes be repaired. If carbonized or sooted up, the plug may readily be cleaned with a stiff brush and gasoline. Do not scrape with a knife, as it merely rubs the carbon into the surface of the porcelain.

The gap between plug terminals should be between 1/40 and 1/32 in. It should not be more nor less than this amount for efficient ignition. A smooth dime is a good gauge to use for setting this gap.

Poor Compression.—Poor compression is one of the common causes for lack of power. Unless the compression pressure is high enough, the explosion will be lacking in force and the engine will be weak. The engine can be turned by hand, with the ignition off, throttle open, and the compression noted in each cylinder, or a more accurate way is to remove the spark plug and screw in a

small pressure gauge, which should show from 60 to 80 lbs. at the end of the compression stroke, depending on the make of engine. Loss of compression is commonly due to leaky or improperly seated valves, or to leaky joints. Leaky thread joints, valve caps, and cracks in cylinder are common causes for loss of compression. These can be detected by a hissing sound or, if the suspected leak is covered with gasoline or oil, the leak will show itself by air bubbling through the oil. If the trouble cannot be located in this manner attention should be given to the valves.

As a rule, the intake valve requires less attention than the exhaust valve, because the former comes into contact with the cool fresh fuel charges, whereas the latter is apt to become fouled and burnt by the hot and dirty exhaust gases. A frequent cause of leaky valves is carbon deposit on the valve seats. These deposits prevent the proper seating of the valves. The remedy is to clean and grind the valves.

Loose or Broken Terminals.—If there is no current at the plug, the wiring system should be examined carefully for dirty and loose terminals, broken connections, and oil soaked and wet wiring. If the insulation has been worn off, the current is liable to be short-circuited or grounded through the engine or frame of the car. Defective or poor contacts at switches may also be the cause of no current at the plugs.

Weak Batteries or Magneto.—Weak or exhausted batteries are a common source of trouble. If the batteries are suspected, they should be tested with a small "ammeter." If any one of the dry cells shows less than 6 amp., it should be taken out and replaced with a new one. One weak coil will greatly interfere with the operation of the others in the set. Occasionally, a weak dry cell can be livened up temporarily by boring a small hole through the top and pouring in a small quantity or water, or better still, of vinegar. The effect is, however, only a temporary one.

Dry batteries should always be kept perfectly dry. If they become wet on the outside, there is a tendency for the battery to be short-circuited and exhaust itself. Especially is this true if water spills on the top of the battery between the terminals.

If the storage battery appears dead or shows lack of energy, it may be due to one of the following causes of trouble: (a) discharged; (b) electrolyte in the jar too low; (c) specific gravity of electrolyte too low; or (d) plates sulphated. These troubles are fully treated in the chapter on starting and lighting under the heading of Storage Batteries.

If the ignition trouble has been located in the magneto side of the system and the plugs and wiring system have been found in good working order, attention should be turned to the magneto itself. The distributor plate should be thoroughly cleaned with gasoline to remove any foreign matter which may have collected after considerable use. After attending to this, it should be determined whether or not the magneto is generating current. This can be done by disconnecting the magneto cables and watching the safety spark gap while cranking the engine. If no spark appears there the trouble is in the magneto itself.

The contact points may be pitted or burned. They should be filed until they meet each other squarely. Be sure that the adjustment is properly made.

The carbon or collector brushes may be dirty or worn. They should be cleaned, or if badly worn, replaced with new brushes.

It occasionally happens that the magnets become weak or demagnetized. They may possibly be placed in the magneto in the wrong position. If weak or

demagnetized, they should be remagnetized before being replaced. Care should be exercised in getting the like poles of the magnets together on the same side of the magneto. Most magnets are marked with an "N" indicating the north pole.

Defective Wiring.—If there is no current at the plug, the wiring system should be examined carefully for dirty and loose terminals, broken connections, and oil soaked and wet wiring. If the insulation has been worn off, the current it liable to be short-circuited or grounded through the engine or frame of the car. Defective or poor contacts at switches may also be the cause of no current at the plugs.

Coil Not Properly Adjusted.—A frequent cause of no current at the plug is coil trouble especially where a vibrating coil is used for each cylinder. The vibrator points become pitted, out of line and burned, making good contact impossible. The tension on the vibrator spring becomes changed, permitting the coil to consume too much or too little current.

Burned or pitted points should be filed flat with a thin smooth file, or hammered flat with a small hammer. In either case the points should be so shaped as to meet each other squarely.

If it becomes necessary to adjust the tension on the vibrators, the tension should be entirely taken off and gradually increased until the engine runs satisfactorily without wissing. It is very important to have all the units adjusted alike. This can be easily done after a little experience. The most accurate method of coil adjustment is with a coil current indicator by which the amount of current consumed is measured. Coils are built to consume about ½ amp. and the tension should be adjusted so that the current consumption of each coil is not much greater than this amount.

Gasoline Feed Stopped Up.—A weak mixture can be detected by back-firing through the carburetor and by occasional muffler explosions. A weak mixture, being a slow burning mixture, is still burning when the intake valve opens for the following charge. This permits the flame to shoot back through the manifold into the carburetor. A weak mixture should not be confused with an improperly timed intake valve which opens before the burning charge has been exhausted. If the intake valve has a weak spring which does not close the valve properly, it may permit back-firing through the carburetor. The explosions caused by the valve trouble are usually more violent than a backfire due to weak mixture. A weak mixture as low speeds is caused generally by too little gasoline and at high speeds by too much auxiliary air and the carburetor should be adjusted accordingly.

An air leak in the manifold connections will dilute the mixture with air and cause a weak mixture and back-firing. These leaks should be remedied before the carburetor adjustments are changed.

A stuck or bent or obstructed gasoline needle valve may cause a weak mixture by shutting off the supply of gasoline. The remedy is obvious.

If, after priming, the engine starts and suddenly dies down, the gasoline supply may be exhausted, the feed pipe may be clogged, or a piece of dirt may have worked into the needle valve. If there is a supply of gasoline and the trouble is found to be due to dirt in the feed system, the feed pipe may be disconnected and the dirt blown out. A particle of dirt in the needle valve may be removed by screwing the valve shut and then opening it the proper amount. This trouble and also the one due to water in the gasoline can be prevented by straining the gasoline through a chamois skin before putting it into the main tank.

Needle Valve Bent or Stuck.—A weak mixture can be detected by back-firing through the carburetor and by occasional muffler explosions. A weak mixture, being a slow burning mixture, is still burning when the intake valve opens for the following charge. This permits the flame to shoot back through the manifold into the carburetor. A weak mixture should not be confused with an improperly timed intake valve which opens before the burning charge has been exhausted. If the intake valve has a weak spring which does not close the valve properly, it may permit back-firing through the carburetor. The explosions caused by the valve trouble are usually more violent than a back-fire due to weak mixture. A weak mixture at low speeds is caused generally by too little gasoline and at high speeds by too much auxiliary air and the carburetor should be adjusted accordingly.

An air leak in the manifold connections will dilute the mixture with air and cause a weak mixture and back-firing. These leaks should be remedied before the carburetor adjustments are changed.

A stuck or bent or obstructed gasoline needle valve may cause a weak mixture by shutting off the supply of gasoline. The remedy is obvious.

Water in Gasoline.—It sometimes happens that the carburetor becomes loaded with water, due to the fact that it can neither evaporate nor get out. This water prevents the gasoline from getting in. The water should be drained from the carburetor drain cock.

Poor Circulation.—Poor circulation in the cooling system is one of the common sources of trouble and when neglected is liable to give the driver many uneasy moments. The water system must be kept filled with water. This is of especial importance in the thermo syphon system, in which the water level must at all times be above the return pipe from the engine to the radiator in order to have the circulation continue.

Excessive Lubrication.—The usual lubricating troubles are those due to the use of the wrong kind of lubricating oil or too much or too little of it. An engine with loose fitting pistons, and an air-cooled engine usually requires a heavier oil than a water-cooled engine. It is very essential that a true gas engine cylinder oil be used for cylinder lubrication because it alone satisfies the requirements. Poor lubricating oil is expensive at any price and it is good economy to use the best cylinder oil obtainable. In this manner the recommendations of the manufacturer should be followed out.

An excess of lubricating oil shows itself by a white bluish smoke coming from the muffler. In addition to this, an excess of lubricating oil causes the formation of a pasty carbon deposit in the cylinder, which causes the engine to overheat.

The important things to look after are to be sure that there is a sufficient supply of oil and that the oil pump is in working order. The crank case should be drained and washed out with kerosene and new oil put in every 1,000 miles.

Engine Overheats

Engine Lubrication.—The usual lubricating troubles are those due to the use of the wrong kind of lubricating oil or too much or too little of it. An engine with loose fitting pistons requires a heavier oil than one with tight fitting pistons, and an air-cooled engine usually requires a heavier oil than a water-cooled engine. It is very essential that a true gas engine cylinder oil be used for cylinder lubrication because it alone satisfies the requirements. Poor lubricating oil is expensive at any price and it is good economy to use the best cylinder oil obtainable. In this matter the recommendations of the manufacturer should be followed out.

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The important things to look after are to be sure that there is a sufficient supply of oil and that the oil pump is in working order. The crank case should be drained and washed out with kerosene and new oil put in every 1,000 miles.

Poor circulation.—Poor circulation in the cooling system is one of the common sources of trouble and when neglected is liable to give the motorist many uneasy moments. The water system must be kept filled with water. This is of especial importance in the thermo syphon system, in which the water level must at all times be above the return pipe from the engine to the radiator in order to have the circulation continue.

A worn pump may cause poor circulation, because in most cases the thermo syphon effect in a forced system of circulation is not enough to keep the water at the proper rate.

Sediment in the radiator and scale in the engine jacket may seriously interfere with the circulation of the water. Such clogging of the system comes from the continual heating and cooling of the impure water used. This emphasizes the desirability of using pure water or rain water in the radiator. The sediment and hard scale may be removed as follows: Open the drain cock in the bottom of the radiator and introduce the end of a hose in the filler of the radiator. Run the motor for about 15 minutes and the fresh water from the hose will clean out the loose sediment or scale in the water jackets and radiator. Through this process, a supply of fresh water is constantly entering the system and passing through the water jackets while the motor is running.

Next, dissolve as much ordinary washing soda as can be dissolved in enough water to fill the radiator. Then run the motor with a retarded spark until the water is brought to the boiling point. Allow this solution to remain in the motor and radiator for several hours, after which again open the drain cock and, with a hose, again flush out the entire system with fresh water as before. In extreme cases it would be well to repeat this process several times. The final operation of flushing out with fresh water should be thoroughly done. If any of the washing soda solution is left in the motor or radiator, it may result in undesirable chemical action.

When rubber hose forms a part of the circulating system, a kink or twist in the hose may possibly cause poor circulation of the water. The inside fibers of the hose also tend to come loose and clog the system.

In the case of thermo syphon cooling systems or in air-cooled motors, the operation of the fan is essential to the successful operation of the cooling system. If the fan belt breaks or slips, or the fan blades are bent, the air circulation through the radiator is interfered with and consequently the water is not properly cooled.

The attention which must be given to the cooling system in winter to prevent freezing has been thoroughly taken up in Chap. V. One thing to be watched in winter running is the temperature of the water. If the weather is excessively cold, the water may be cooled below the efficient running temperature of from 180° to 200°. In this case, the radiator front should be partially covered in order to keep out a part of the cold air. This will also keep the water warm for a longer time when the car is standing.

Too Rich a Mixture.—A rich mixture shows itself by black smoke coming from the muffler, and by overheating and missing of the engine. Not only is fuel wasted, but the cylinders become fouled and carbonized. A mixture too rich at slow speeds should be corrected by cutting down on the gasoline, and at high speeds by increasing the auxiliary air. An auxiliary air spring which sticks, a restricted air opening, or a flooded carburetor will cause an overrich mixture.

Mixture Too Weak.—A weak mixture can be detected by back-firing through the carburetor and by occasional muffler explosions. A weak mixture, being a slow burning mixture, is still burning when the intake valve opens for the following charge. This permits the flame to shoot back through the manifold into the carburetor. A weak mixture should not be confused with an improperly timed intake valve which opens before the burning charge has been exhausted. If the intake valve has a weak spring which does not close the valve properly, it may permit back-firing through the carburetor. The explosions caused by the valve trouble are usually more violent than a back-fire due to weak mixture. A weak mixture at low speeds is caused generally by too little gasoline and at high speeds by too much auxiliary air and the carburetnr should be adjusted accordingly.

An aid leak in the manifold connections will dilute the mixture with air and cause a weak mixture and back-firing. These leaks should be remedied before the carburetor adjustments are changed.

A stuck or bent or obstructed gasoline needle valve may cause a weak mixture by shutting off the supply of gasoline. The remedy is obvious.

Running with Spark Retarded.—If the engine kicks back after cranking, the spark is too far advanced and should be retarded so that the spark does not occur until the piston has passed the dead center. The tendency of an early spark on startng is to cause the engine to start backward. Too early a spark at slow speeds will make the engine knock and will cause the car to jerk.

A retarded spark causes the engine to overheat and lose considerable of its power. There is no advantage of retarding the spark past center, even in starting. When running it should be advanced in proportion to the speed.

On care equipped with automatic spark advance, the troubles due to early and late spark are not experienced. Pre-ignition from other causes, however, may occur with either type of spark advance.

Carbon Deposit in Cylinders.—After the engine has been run for some time, carbon deposits are liable to collect in the cylinder and on the pistons, especially if too much lubricating oil or gasoline has been used. The carbon deposits resulting from too much gasoline are hard, dry and brittle. These deposits, if allowed to collect, become hot from the heat of explosions, and cause pre-ignition of the fresh charge of gas.

The best methods of removing carbon deposits are to scrape or to burn them out by means of an oxygen flame. The latter method is quicker and by far the most convenient. The following method is recommended by the Overland Company for the removal of carbon by scraping:

To scrape the cylinders, remove both inlet and exhaust valve caps and turn the motor over until the pistons of two cylinders are at their top centers. The scraping off of the deposit is done by means of tools of different shapes, the tools being bent so as to reach the piston head and the sides and tops of the cylinders. Scrape all removed carbon over to the exhaust valve and, when through, turn the motor until the exhaust valve lifts, when the carbon may me scraped past the valve and into the exhaust passage, whence it will be blown out. For a good job, brush the surfaces clean and make sure that

no carbon becomes lodged between the exhaust valve and its seat. Finally wash with kerosene.

In replacing the cylinder plugs over the valves, put graphite grease around the threads; this will make a compression-tight joint and also make it easier to remove the plugs the next time. Likewise, be sure to replace the copper gaskets under the plugs.

It is an excellent plan to attend to removing the carbon and to grinding the valves together at the same time.

Kerosene is also used for the removal of carbon from the cylinders. Pour two or three tablespoonfuls of kerosene through the priming cocks while the engine is warm. It has a strong solvent action on any gummy binding material in the carbon and can be spread over the entire cylinder by cranking the engine a few times around. Some motorists inject the kerosene through the air valve of the carburetor just before the engine is stopped preparatory to putting it away for the night. Kerosene will not remove a hard carbon deposit, but it will prevent it from forming if used regularly about once a week.

Running the engine on alcohol for a few minutes is another device that is sometimes used for burning out carbon deposits.

Premature ignition is caused by particles of carbon, sharp corners, etc., becoming incandescent from the heat of explosion and igniting the charge on the compression stroke before the spark occurs. Premature ignition occurs generally when the engine has been loaded quite heavily at a slow speed, as when going up a steep hill on high speed. Any engine will have premature ignition if it becomes excessively hot under low speed and heavy load, but the tendency to pre-ignite is much more marked if the cylinder is full of carbon deposits. These carbon deposits should be cleaned out as explained before.

Engine Stops

Gasoline Tank Empty.—It sometimes happens that if a pressure gasoline system is used, the pressure becomes too low to force the gasoline from the main tank to the auxiliary tank. This causes a lack of fuel at the carburetor. A hand pump is usually furnished for increasing this air pressure on the tank.

If the car is equipped with a gravity feed system, the gasoline may fail to run to the carburetor when ascending a steep hill. It sometimes becomes necessary to back the car uphill, in which case the gasoline will run to the carburetor without difficulty.

Water in Gasoline.—It sometimes happens that the carburetor becomes loaded with water, due to the fact that it can neither evaporate nor get out. This water prevents the gasoline from getting in. The water should be drained from the carburetor drain cock.

Carburetor Flooded.—If the carburetor float becomes gasoline soaked or filled with gasoline, it will not shut off the gasoline float valve and the carburetor float chamber will become filled with gasoline. The remedy is to take the float out and if it is made of cork, have it dried out, painted with shellac and baked. If of the hollow metal type, have the float emptied and the hole soldered. A small particle of dirt under the float valve will also cause the carburetor to become flooded.

Lack of Pressure on Gasoline Tank.—It sometimes happens that if a pressure gasoline system is used, the pressure becomes too low to force the gasoline from the main tank to the auxiliary tank. This causes a lack of fuel in the carburetor. A hand pump is usually furnished for increasing this air pressure on the tank.

If the car is equipped with a gravity feed system, the gasoline may fail to run to the carburetor when ascending a steep hill. It sometimes becomes necessary to back the car uphill, in which case the gasoline will run to the carburetor without difficulty.

Overheating Due to Poor Circulation or Lack of Lubrication.—The usual lubricating troubles are those due to the use of the wrong kind of lubricating oil or too much or too little of it. An engine with loose fitting pistons requires a heavier oil than one with tight fitting pistons, and an air-cooled engine usually requires a heavier oil than a water-cooled engine. It is very essential that a true gas engine cylinder oil be used for cylinder lubrication because it alone satisfies the requirements. Poor lubricating oil is expensive at any price and it is good economy to use the best cylinder oil obtainable. In this matter the recommendations of the manufacturer should be followed out.

An excess of lubricating oil shows itself by a white bluish smoke coming from the muffler. In addition to this, an excess of lubricating oil causes the formation of a pasty carbon deposit in the cylinder, which causes the engine to overheat.

The important things to look after are to be sure that there is a sufficient supply of oil and that the oil pump is in working order. The crank case should be drained and washed out with kerosene and new oil put in every 1,000 miles.

Poor circulation in the cooling system is one of the common sources of trouble and when neglected is liable to give the motorist many uneasy moments. The water system must be kept filled with water. This is of especial importance in the thermo syphon system, in which the water level must at all times be above the return pipe from the engine to the radiator in order to have the circulation continue.

A worn pump may cause poor circulation, because in most cases the thermo syphon effect in a forced system of circulation is not enough to keep the water moving at the proper rate.

Sediment in the radiator and scale in the engine jacket may seriously interfere with the circulation of the water. Such clogging of the impure water used comes from the continual heating and cooling of the impure water used. This emphasizes the desirability of using pure water or rain water in the radiator. The sediment and hard scale may be removed as follows: Open the drain cock in the bottom of the radiator and introduce the end of a hose in the filler of the radiator. Run the motor for about 15 minutes and the fresh water from the hose will clean out the loose sediment or scale in the water jackets and radiator. Through this process, a supply of fresh water is constantly entering the system and passing through the water jackets while the motor is running.

Next, dissolve as much ordinary washing soda as can be dissolved in enough water to fill the radiator. Then run the motor with a retarded spark until the water is brought up to the boiling point. Allow this solution to remain in the motor and radiator for several hours, after which again open the drain cock and, with a hose, again flush out the entire system with fresh water as before. In extreme cases it would be well to repeat this process several times. The final operation of flushing out with fresh water should be thoroughly done. If any of the washing soda solution is left in the motor or radiator, it may result in undesirable chemical action.

When rubber hose forms a part of the circulating system, a kink or twist in the hose may possibly cause poor circulation of the water. The inside fibers of the hose also tend to come loose and clog the system.

In the case of thermo syphon cooling systems or in air-cooled motors, the operation of the fan is essential to the successful operation of the cooling system. If the fan belt breaks or slips, or the fan blades are bent, the air circulation through the radiator is interfered with and consequently the water is not properly cooled.

One thing to be watched in winter running is the temperature of the water. If the weather is excessively cold, the water may be cooled below the efficient running temperature of from 180° to 200°. In this case, the radiator front should be partially covered in order to keep out a part of the cold air. This will also keep the water warm for a longer time when the car is standing.

Short-circuiting of Wires or Terminals.—If there is no current at the plug, the wiring system should be examined carefully for dirty or loose terminals, broken connections, and oil soaked and wet wiring. If the insulation has been worn off, the current is liable to be short-circuited or grounded through the engine or frame of the car. Defective or poor contacts at switches may also be the cause of no current at the plugs.

If no current is obtained in the secondary of a coil, when the vibrator is working as it should, the trouble is probably due to a broken wire inside of the coil. It sometimes happens that the binding post wires become loose from the post just inside of the coil. If only a slight spark can be obtained, the insulation on the inside wire may be broken down, thus causing a short circuit of the current. Obviously there is no remedy but to replace the coil.

Disconnected or Broken Wires.—If there is no current at the plug, the wiring system should be examined carefully for dirty and loose terminals, broken connections, and oil soaked and wet wiring. If the insulation has been worn off, the current is liable to be short-circuited or grounded through the engine or frame of the car. Defective or poor contacts at switches may also be the cause of no current at the plugs.

Wet Batteries or Magneto.—If there is no current at the plug, the wiring system should be examined carefully for dirty and loose terminals, broken connections, and oil soaked and wet wiring. If the insulation has been worn off, the current is liable to be short-circuited or grounded through the engine or frame of the car. Defective or poor contacts at switches may also be the cause of no current at the plugs.

Weak or exhausted batteries are a common source of trouble. If the batteries are suspected, they should be tested with a small "ammeter." If any one of the dry cells shows less than 6 amp., it should be taken out and replaced with a new one. One weak cell will greatly interfere with the operation of the others in the set. Occasionally, a weak dry cell can be livened up temporarily by boring a small hole through the top and pouring in a small quantity of water, or better still, of vinegar. The effect is, however, only a temporary one.

Dry batteries should always be kept perfectly dry. If they become wet on the outside, there is a tendency for the battery to be short-circuited and exhaust itself. Especially is this true if water spills on the top of the battery between the terminals.

Engine Knocks.

Carbon Deposits in Cylinder and On Piston Heads.—After the engine has been run for some time, carbon deposits are liable to collect in the cylinder and on the pistons, especially if too much lubricating oil or gasoline has been used. The carbon deposit resulting from too much lubricating oil is a sticky

substance, while that from too much gasoline is hard, dry, and brittle. These deposits, if allowed to collect, become hot from the heat of explosions, and cause pre-ignition of the fresh charge of gas.

The best methods of removing carbon deposit are to scrape it out or to burn it out by means of an oxygen flame. The latter method is quicker and by far the most convenient. .The following method is recommended by the Overland Company for the removal of carbon by scraping:

To scrape the cylinders, remove both the inlet and exhaust valve caps, and turn the motor over until the pistons of two cylinders are at their top centers. The scraping off of the deposit is done by means of tools of different shapes, the tools being bent so as to reach the piston head and the sides and tops of the cylinders. Scrape all removed carbon over to the exhaust valve and, when through, turn the motor until the exhaust valve lifts, when the carbon may be scraped past the valve and into the exhaust passage, whence it will be blown out. For a good job, brush the surfaces clean and make sure that no carbon becomes lodged between the exhaust valve and its seat. Finally wash with kerosene.

In replacing the cylinder plugs over the valves, put graphite grease around the threads; this will make a compression-tight joint and also make it easier to remove the plugs the next time. Likewise, be sure to replace the copper gaskets under the plugs.

It is an excellent plan to attend to removing the carbon and to grinding the valves together at the same time,

Kerosene is also used for the removal of carbon from the cylinders. Pour two or three tablespoonfuls of kerosene through the priming cocks while the engine is warm. It has a strong solvent action on any gummy binding material in the carbon and can be spread over the entire cylinder by cranking the engine a few times around. Some motorists inject kerosene through the air valve of the carburetor just before the engine is stopped preparatory to putting it away for the night. Kerosene will not remove a hard carbon deposit, but it will prevent it from forming if used regularly about once a week.

Running the engine on alcohol for a few minutes is another device that is sometimes used for burning out carbon deposits.

Premature ignition is caused by particles of carbon, sharp corners, etc., becoming incandescent from the heat of explosion and igniting the charge on the compression stroke before the spark occurs. Premature ignition occurs generally when the engine has been loaded quite heavily at a slow speed, as when going up a steep hill on high speed. Any engine will have premature ignition if it becomes excessively hot under low speed and heavy load, but the tendency to pre-ignite is much more marked if the cylinder is full of carbon deposits. These carbon deposits should be cleaned out as explained before.

Spark Too Far Advanced.—If the engine kicks back after cranking, the spark is too far advanced and should be retarded so that the spark does not occur until the piston has passed the dead center. The tendency of an early spark on starting is to cause the engine to start backward. Too early a spark at slow speeds will make the engine knock and will cause the car to jerk.

A retarded spark causes the engine to overheat and lose considerable of its power. There is no advantage in retarding the spark past center, even in starting. When running it should be advanced in proportion to the speed.

On cars equipped with automatic spark advance, the troubles due to early and late spark are not experienced. Pre-ignition from other causes, however, may occur with either type of spark advance.

Running Motor Slow When Pulling Heavy Load On Direct Drive.—If the engine kicks back after cranking, the spark is too far advanced and should be retarded so that the spark does not occur until the piston has passed dead center. The tendency of an early spark on starting is to cause the engine to start backward. Too early a spark at slow speeds will make the engine knock and will cause the car to jerk.

A retarded spark causes the engine to overheat and lose considerable of its power. There is no advantage of retarding the spark past center, even in starting. When running it should be advanced in proportion to the speed.

On cars equipped with automatic spark advance, the troubles due to early and late spark are not experienced. Pre-ignition from other causes, however, may occur with either type of spark advance.

Faulty Lubrication.—The usual lubricating troubles are those due to the use of the wrong kind of lubricating oil or too much or too little of it. An engine with loose fitting pistons requires a heavier oil than one with tight fitting pistons, and an air-cooled engine usually requires a heavier oil than a water-cooled engine. It is very essential that a true gas engine cylinder oil be used for cylinder lubrication because it alone satisfies the requirements. Poor lubricating oil is expensive at any proce and it is good economy to use the best cylinder oil obtainable. In this matter the recommendations of the manufacturers should be followed out.

An excess of lubricating oil shows itself by a white bluish smoke coming from the muffler. In addition to this, an excess of lubricating oil causes the formation of a pasty carbon deposit in the cylinder, which causes the engine to overheat.

The important things to look after are to be sure that there is a sufficient supply of oil and that the oil pump is in working order. The crank case should be drained and washed out with kerosene and new oil put in every 1,000 miles.

Engine Overheated.—Premature ignition is caused by particles of carbon, sharp corners, etc., becoming incandescent from the heat of explosion and igniting the charge on the compression stroke before the stroke occurs. Premature ignition occurs generally when the engine has been loaded quite heavily at a slow speed, as when going up a steep hill on high speed. Any engine will have premature ignition if it becomes excessively hot under low speed and heavy load, but the tendency to pre-ignite is much more marked if the cylinder is full of carbon deposits. These carbon deposits should be cleaned out as explained before.

Loose Connecting Rod Bearings.—The common bearing troubles are those caused by the bearings becoming worn and loose, with a consequent knocking. faulty lubrication, clogged oil pipes and oil holes, and dirty oil are the main causes of worn bearings. The bearings which are most liable to give trouble are the wrist pin bearings, the connecting rod bearings, and the main crank bearings. After a bearing has been excessively hot, it should be refitted by a mechanic. A loose bearing can be tightened on the pin by removing the liners or shims, or by being refitted.

Loose Piston.—A loose piston or scored cylinder walls will cause a marked loss of compression. If the piston is not too loose, slightly larger rings may be put on. Sometimes the blowing back can be remedied by using a heavier cylinder oil. This will, to some extent, remedy the trouble caused by scored cylinder walls, although if too badly cut, they must be re-bored and new pistons or rings fitted in. Again, this is the work of an experienced mechanic.

Loose Crank Shaft Bearing.—The common bearing troubles are those caused by the bearings becoming worn and loose, with a consequent knocking. Faulty

lubrication, clogged oil pipes and oil holes, and dirty oil are the main causes of worn bearings. The bearings which are most liable to give trouble are the wrist pin bearings, the connecting rod bearings, and the main crank bearings. After a bearing has been excessively hot, it should be retightened on the pin by removing the liners or shims, or by being refitted.

Engine Will Not Stop

Short Circuit in Switch.

Magneto Ground May Be Disconnected.

Overheating and Carbon Deposits.—Premature ignition is caused by particles of carbon, sharp corners, etc., becoming incandescent from the heat of the explosion and igniting the charge on the compression stroke before the spark occurs. Premature ignition occurs generally when the engine has been loaded quite heavily at a slow speed, as when going up a steep hill on high speed. Any engine will have premature ignition if it becomes excessively hot under low speed and heavy load, but the tendency to pre-ignite is much more marked if the cylinder is full of carbon deposits. The carbon deposits should be cleaned out as explained before.

Lack of Power

Poor Compression.—Poor compression is one of the common causes of lack of power. Unless the compression pressure is high enough, the explosion will be lacking in force and the engine will be weak. The engine can be turned by hand, with the ignition off, throttle open, and the compression noted in each cylinder, or a more accurate way is to remove the spark plug and screw in a small pressure gauge, which should show from 60 to 80 lbs. at the end of the compression stroke, depending of the make of the engine. Loss of compression is commonly due to leaky or improperly seated valves, or to leaky joints. Leaky thread joints, valve caps, and cracks in cylinder are common causes for loss of compression. These can be detected by a hissing sound or, if the suspected leak is covered with gasoline or oil, the leak will show itself by bubbling through the oil. If the trouble cannot be located in this manner attention should be given to the valves.

As a rule, the intake valve requires less attention than the exhaust valve, because the former comes into contact with the cool fresh fuel charges, whereas the latter is apt to become fouled and burnt by the hot and dirty exhaust gases. A frequent cause of leaky valves is carbon deposit on the valve seats. These deposits prevent the proper seating of the valve. The remedy is to clean and grind them.

Too Weak or Too Rich a Mixture.—A rich mixture shows itself by black smoke coming from the muffler, and by overheating and missing of the engine. Not only is fuel wasted, but the cylinders become fouled and carbonized. A mixture too rich at slow speeds should be corrected by cutting down on the gasoline, and at high speeds by increasing the auxiliary air. An auxiliary air spring which sticks, a restricted air opening, or a flooded carburetor will cause an overrich mixture.

A weak mixture can be detected by back-firing through the carburetor and by occasional muffler explosions. A weak mixture, being a slow burning mixture, is still burning when the intake valve opens for the following charge. This permits the flame to shoot back through the manifold into the carburetor. A weak mixture should not be confused with an improperly timed intake valve which opens before the burning charge has been exhausted. If the intake

valve has a weak spring which does not close the valve properly, it may permit back-firing through the carburetor. The explosions caused by the valve trouble are usually more violent than a back-fire due to weak mixture. A weak mixture at low speeds is caused generally by too little gasoline and at high speeds by too much auxiliary air and the carburetor should be adjusted accordingly.

An air leak in the manifold connections will dilute the mixture with air and cause a weak mixture and back-firing. These leaks should be remedied before the carburetor adjustments are changed.

A stuck or bent or obstructed gasoline needle valve may cause a weak mixture by shutting off the supply of gasoline. The remedy is obvious.

Weak Spark.—Weak or exhausted batteries are a common source of trouble. If the batteries are suspected, they should be tested with a small "ammeter." If any one of the dry cells show less than 6 amp., it should be taken out and replaced with a new one. One weak cell will greatly interfere with the operation of the others in the set. Occasionally, a weak dry cell can be livened up temporarily by boring a small hole through the top and pouring in a small quantity of water, or better still, of vinegar. The effect is, however, only a temporary one.

Dry batteries should always be kept perfectly dry. If they become wet on the outside, there is a tendency for the battery to be short-circuited and exhaust itself. Especially is this true if water spills on top of the battery between the terminals.

If the storage battery appears dead or shows lack of energy, it may be due to one of the following causes of trouble: (a) discharged; (b) electrolyte in the jar too low; (c) specific gravity of electrolyte too low; or (d) plates sulphated. These troubles treated in the chapter on starting and lighting under the heading of Storage Batteries.

If the ignition trouble has been located in the magneto side of the system and the plugs and wiring system have been found in good working order, attention should be turned to the magneto itself. The distributor plate should be thoroughly cleaned with gasoline to remove any foreign matter which may have collected after considerable use. After attending to this, it should be determined whether or not the magneto is generating current. This can be done by disconnecting the magneto cables and watching the safety spark gap while cranking the engine. If no spark appears there the trouble is in the magneto itself.

The contact points may be pitted or burned. They should be filed until they meet each other squarely. Be sure that the adjustment is properly made.

The carbon or collector brushes may be dirty or worn. They should be cleaned or if badly worn replaced with new brushes.

It occasionally happens that the magnets become weak or demagnetized. They may possibly be placed in the magneto in the wrong position. If weak or demagnetized, they should be remagnetized before being replaced. Care should be exercised in getting the like poles of the magnets together on the same side of the magneto. Most magnets are marked with an "N" indicating the north pole.

A frequent cause of no current at the plug is coil trouble, especially where a vibrating coil is used for each cylinder. The vibrator points become pitted, out of line, and burned, making good contact impossible. The tension on the vibrator spring becomes changed, permitting the coil to consume too much or too little current.

Burned or pitted points should be filed flat with a thin smooth file, or hammered flat with a small hammer. In either case the points should be so shaped as to meet each other squarely.

If it becomes necessary to adjust the tension on the vibrators, the tension should be entirely taken off and gradually increased until the engine runs satisfactorily without missing. It is very important to have all the units adjusted alike. This can easily be done after a little experience. The most accurate method of coil adjustment is with a coil current indicator by which the amount of current consumed is measured. Coils are built to consume about ½ amp. and the tension should be adjusted so that the current consumption of each coil is not much greater than this amount.

Lack of Lubrication.—The usual lubrication troubles are those due to the use of the wrong kind of lubricating oil or too much or too little of it. An engine with loose fitting pistons requires a heavier oil than one with tight fitting pistons, and an air-cooled engine usually requires a heavier oil than a water-cooled engine. It is very essential that a true gas engine cylinder oil be used for cylinder lubrication because it alone satisfies the requirements. Poor lubricating oil is expensive at any price and it is good economy to use the best cylinder oil obtainable. In this matter the recommendations of the manufacturer should be followed out.

An excess of lubricating oil shows itself by a white bluish smoke coming from the muffler. In addition to this, an excess of lubricating oil causes the formation of a pasty carbon deposit in the cylinder, which causes the engine to overheat.

The important things to look after are to be sure that there is a sufficient supply of oil and that the oil pump is in working order. The crank case should be drained and washed out with kerosene and new oil put in every 1,000 miles.

Lack of Cooling Water.—A defective plug may be broken, oil soaked, carbonized, or the air gap between terminals too much or too little. If the plug is broken, it usually must be replaced by a new plug. A plug with a loose center electrode may sometimes be repaired. If carbonized or sooted up, the plug may readily be cleaned with a stiff brush and gasoline. Do not scrape with a knife, as it merely rubs the carbon into the surface of the porcelain.

The gap between plug terminals should be between 1/40 and 1/32 in. It should not be more or less than this amount for efficient ignition. A smooth dime is a good gauge to use for setting this gap.

Lack of Gasoline.—A frequent cause of no current at the plug is coil trouble, especially where a vibrating coil is used for each cylinder. The vibrator points become pitted, out of line, and burned, making good contact impossible. The tension on the vibrator spring becomes changed, permitting the coil to consume too much or too little current.

In the case of burned or pitted points, they should be filed flat with a thin smooth file, or hammered flat with a small hammer. In either case the points should be so shaped as to meet each other squarely.

If it becomes necessary to adjust the tension on the vibrators, the tension should be entirely taken off and gradually increased until the engine runs satisfactorily without missing. It is very important to have all the units adjusted alike. This can easily be done after a little experience. The most accurate method of coil adjustment is with a coil current indicator by which the amount of current consumed is measured. Coils are built to consume about ½ amp. and the tension should be adjusted so that the current consumption of each coil is not much greater than this amount.

Dragging Brakes.—It is very necessary that the brakes be kept in perfect working order at all times. It is more necessary to be able to stop the car in emergencies than to start it. If the brakes fail to hold, it may be that the drum and band facings have become covered with oil and dirt, or the band facings may be worn. In the latter case, new facings are necessary in most cases, but adjustments can be made for slight wear.

The brakes may bind or stick, due to the tight adjustments. With tight adjustments, the motor is pulling the car against the friction of the brakes at all times.

If the brakes are not adjusted the same on each side of the car, there will be a tendency for the car to skid when the brakes are applied. The braking effect comes on only one wheel and this tends to swing the car around. Many cars are provided with brake equalizers which allow them to work together.

Slipping Clutch.—Clutch troubles are about the same in either the cone, plate, or multiple-disc types. The clutch either slips, engages harshly, grabs, or refuses to release. If it slips, the full power of the engine is not transmitted and the clutch becomes hot from the friction. In the cone and dry-plate types, a coating of oil on the facings will cause slipping. The wear of the facing or weak or broken springs will cause the same results. If the slipping is caused by grease and dirt, the clutch leather should be thoroughly cleaned with a rag dipped in kerosene.

Back Firing Through Carburetor

Choked Muffler Causing Back Pressure.—Back-Firing Through Carburetor.

Improper Needle Valve Adjustment.—A weak mixture can be detected by back-firing through the carburetor and by occasional muffler explosions. A weak mixture, being a slow burning mixture, is still burning when the intake valve opens for the following charge. This permits the flame to shoot back through the manifold into the carburetor. A weak mixture should not be confused with an improperly timed intake valve which opens before the burning charge has been exhausted. If the intake valve has a weak spring which does not close the valve properly, it may permit back-firing through the carburetor. The exulosions caused by the valve trouble are usually more violent than a back-fire due to weak mixture. A weak mixture at low speeds is caused generally by too little gasoline and at high speeds by too much auxiliary air and the carburetor should be adjusted accordingly.

An air leak in the manifold connections will dilute the mixture with air and cause a weak mixture and back-firing. These leaks should be remedied before the carburetor adjustments are changed.

A stuck, bent or obstructed gasoline needle valve may cause a weak mixture by shutting off the supply of gasoline. The remedy is obvious.

Dirt in Gasoline Passage or Nozzle.—A stuck or bent or obstructed gasoline needle valve may cause a weak mixture by shutting off the supply of gasoline. The remedy is obvious.

If, after priming, the engine starts and suddenly dies down, the gasoline supply may be exhausted, the feed pipe may be clogged, or a piece of dirt may have worked into the needle valve. If there is a supply of gasoline and the trouble is found to be due to dirt in the feed system, the feed pipe may be disconnected and the dirt blown out. A particle of dirt in the needle valve may be removed by screwing the valve shut and then opening it the proper amount. This trouble and also the one due to water in the gasoline can be

prevented by straining the gasoline through a chamois skin before putting it into the main tank.

Excessive Temperature of the Hot Water Jacket of the Carburetor, Especially in Hot Weather.—This can be remedied by shutting off the water from the carburetor jacket and cutting off the hot air supply.

Spark Retarded Too Far.—A weak mixture can be detected by back-firing through the carburetor and by occasional muffler explosions. A weak mixture, being a slow burning mixture, is still burning when the intake valve opens for the following charge. This permits the flame to shoot back through the manifold into the carburetor. A weak mixture should not be confused with an improperly timed intake valve which opens before the burning charge has been exhausted. If the intake valve has a weak spring which does not close the valve properly, it may permit back-firing through the carburetor. The explosions caused by the valve trouble are usually more violent than a back-fire due to weak mixture. A weak mixture at low speeds is caused generally by too little gasoline and at high speeds by too much auxiliary air and the carburetor should be adjusted accordingly.

Firing in Muffler

Weak Mixture.—Slow burning exhaust, igniting unburned charge from previous "miss." A weak mixture can be detected by back-firing through the carburetor and by occasional muffler explosions. A weak mixture, being a slow burning mixture, is still burning when the intake valve opens for the following charge. This permits the flame to shoot back through the manifold into the carburetor. A weak mixture should not be confused with an improperly timed intake valve which opens before the burning charge has been adjusted. If the intake valve has a weak spring which does not close the valve properly, it may permit back-firing through the carburetor. The explosions caused by the valve trouble are usually more violent than a back-fire due to weak mixture. A weak mixture at low speeds is caused generally by too little gasoline and at high speeds by too much auxiliary air and the carburetor should be adjusted accordingly.

Valves Out of Time

Too Rich a Gasoline Mixture.—A rich mixture shows itself by black smoke coming from the muffler, and by overheating and missing of the engine. Not only is fuel wasted, but the cylinders become fouled and carbonized. A mixture too rich at slow speeds should be corrected by cutting down on the gasoline, and at high speeds by increasing the auxiliary air. An auxiliary air spring which sticks, a restricted air opening, or a flooded carburetor will cause an overrich mixture.

Transmission Troubles

(*a*) *Clutch Slips.*—Clutch troubles are about the same in either the cone, plate, or multiple-disc types. The clutch either slips, engages harshly, grabs, or refuses to release. If it slips, the full power of the engine is not transmitted and the clutch becomes hot from the friction. In the cone and dry-plate types, a coating of oil on the facings will cause slipping. The wear of the facing or weak or broken springs will cause the same results. If the slipping is caused by grease and dirt, the clutch leather should be thoroughly cleaned with a rag dipped in kerosene.

(*b*) *Clutch Grabs.*—If the clutch engages harshly or grabs suddenly, it may be due to the drying out or hardening of the clutch leathers. A dressing of the facing with neat's-foot oil or castor oil will make it soft and permit gradual engagement. If the clutch springs are too tight, the clutch will "drag" and burn the leather facing.

If a multiple-disc or plate clutch is designed to work in an oil bath, it will engage harshly or grab if the plates become dry. The clutch will also fail to disengage when the pedal is pressed down.

(*c*) *Change Gears Stick.*—If the change gears stick when attempt is made to shift from one gear to another, the shifting members may be stuck on the shaft. If the gears have become burned or teeth broken out, the particles of metal may prevent the movement of the sliding member. Occasionally the shifting lever becomes stuck and refuses to operate the gears. Under ordinary conditions, the change gears should give very little trouble if due attention is given to the lubrication and care to their shifting in operation.

(*d*) *Differential Troubles.*—A noisy differential and driving gear is due to dirt, lack of grease, or broken or worn teeth. In some cases wear can be taken up by the proper adjustments, but these should always be made by an experienced mechanic. The differential, as a rule, will give very little trouble. A break in the differential or in its connections to the wheels is made evident by failure of the engine to propel the car. If the connection to either wheel is broken the other wheel will also lose its power.

Chassis Troubles

(*a*) *Faulty Alignment of Front Wheels.*—Most of the front wheel trouble is due to faulty alignment. The following instructions are given for the adjustment of the front wheels and bearings on the Overland car: The front wheels, when correctly aligned, are not exactly parallel, but "toed-in." To test their proper alignment, jack up both front wheels and with a piece of chalk or a lead pencil held in a fixed position against the tire spin the wheels, drawing a line around the tire casing. The distance between the lines measured at the front of the wheels should be from ⅜ to ½ in. less than in the rear.

"If faulty alignment is due to a bent steering cross-rod, the rod may be straightened out and then adjusted by loosening the lock nut and screwing the rod in or out of its yoke end. Be sure to lock the nut tightly after adjusting.

"If a steering knuckle is bent, it is best to replace it with a new one, because bending it cold will not always restore its correct shape, while heating it may make it too soft for safety.

"The front wheels are also 'set,' or 'cambered,' so that the wheels are a little closer together at the bottom than at the top. This arrangement is desirable on account of the fact that the front wheels are 'dished' so as to make the wheel a sort of flattened cone. This 'dish' of the wheel is compensated by the camber, by which means the lowest wheel spoke is in a vertical position with relation to the road surface. The combined 'toeing-in' and cambering makes for greater strength and also reduces materially the effort required in steering the vehicle. The camber is secured by inclining the axle spindle from its central line, and no adjustment is required in connection with it.

"To see whether the front wheel bearings need adjustment, jack up the wheels. Any looseness will show on rocking the wheels sideways. To tighten the bearing, spin the wheel, at the same time screwing down the adjusting nut until the bearing is so tight that it will stop the rotation of the wheel.

Then back off the nut only enough to allow the wheel to spin. Lock in this position and the bearing will give the best service.

"In general, a somewhat loose bearing is to be preferred to one that is so tight that the rollers are likely to become injured."

(*b*) *Loose Steering Gear.*—With continued use, the worm or screw in the steering gear will wear, and a looseness of the wheel will result. Means are usually provided for taking up this wear. Most drivers prefer to have a small amount of lost motion (about ½ in.) in the wheel, as it makes steering easier and relieves the steering gear from all the road shocks. A great deal of steering gear trouble and wear can be avoided by oiling all the joints regularly. This important point is too often neglected.

(*c*) *Brakes.*—It is very necessary that the brakes be kept in perfect working order at all times. It is more necessary to be able to stop the car in emergencies than to start it. If the brakes fail to hold, it may be that the drum and band facings have become covered with oil and dirt, or the band facings may be worn. In the latter case, new facings are usually necessary, but adjustments can be made for slight wear.

The brakes may bind or stick, due to the tight adjustments. With tight adjustments, the motor is pulling the car against the fricion of the brakes at all times.

If the brakes are not adjusted the same on each side of the car, there will be a tendency for the car to skid when the brakes are applied. The braking effect comes on only one wheel and this tends to swing the car around. Many cars are provided with brake equalizers which allow them to work together.

(*d*) *Springs.*—After a car has been run for some little time, the spring clips become loose and the conditions are then ideal for breaking the springs. Spring breakage occurs mostly with loose clips. Consequently these clips should be tightened every once in a while.

When springs are not lubricated, water works its way in between the leaves and causes them to rust, often to such an extent that they become almost like solid pieces. This causes them to lose much of their spring action. It is a good plan to jack up the frame of the car occasionally, so as to take the weight off the springs, and insert oil and graphite between the leaves. It is also a good plan, about once a year, to have all the springs taken apart, the surfaces thorouhgly cleaned and coated with a thick mixture of oil and graphite.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

LUBRICATION

LECTURE I

OILS AND APPLICATION

Cylinder Oils.—Cylinder oils are usually classified in three grades; light, medium and heavy. Light cylinder oil looks something like the ordinary machine oil, and is slightly more viscous. The medium is somewhat heavier than the light, and might be compared to warm maple syrup. Light and medium oils should be used only on engines which have close-fitting pistons. The heavy oil is used in airclooled engines, in engines that have loose pistons, or that become too hot to use the lighter grade of oil. A good gas engine oil should have a high degree of viscosity at 100° F., a flash point not under 400°, and a fire test of over 300°.

Viscosity.—Viscosity is the property of a liquid by which it has a tendency to resist flowing. Oils are tested for viscosity by being put in a container and allowed to flow through a small opening. The oil that flows the fastest has the least viscosity. In some parts of the automobile it is necessary to use oil with less viscosity than in other parts. Tight fitting bearings should use oil with very little viscosity, while meshed gears should have semi-solid lubricants because the pressure on the rubbing surfaces is very high.

Flash Point.—The flash point is the temperature at which, if an oil be heated and a flame held over the surface, the vapor rising from the oil will burst into flame, but will not continue to burn. A thermometer is placed in the oil bath and the temperature taken at this point.

Fire Test and Cold Test.—Fire test is merely a continuation of the flash point test; that is, the temperature at which the vapor which rises from the oil will continue burning, and not merely flash for a second. Both these tests are used only on cylinder oil.

There is another test that is called the "cold test," which indicates the temperature at which the oil hardens, or becomes so stiff as not to flow. Good cylinder oil should not become so stiff as to prevent reaching the desired points at zero temperature.

(*b*) *Lubrication.*—How to fill oil sump. The engine should be always warm, and chassis should be level in both directions, when testing oil level. Pull out oil level gauge, and if not full to mark, remove cap from breather pipe into which oil is poured through a strainer. Test with gauge until properly filled. Screw cap on breather pipe tight enough so that same will not jar off.

Note to Instructor.—Have student explain lubrication system of motor, pointing out in disassembled motor the circuit of oil from oil sump to final lubrication. Nothing is more important than proper lubrication. To drive a motor with an insufficient supply of oil is gross negligence and one pays dearly when this requirement is ignored.

The oiling system in the "Liberty" motor is automatic. It is a combination of the best features of two systems. The force feed is used to supply oil to the crank shaft, front, center and rear bearings and the timing gears. While

the splash system serves to lubricate the interior of the motor, the pistons, cam shaft, push rods and connecting rod bearings, the oil is circulated by means of a horizontal plunger type pump operated by an eccentric on the cam shaft. The check valves are incorporated in the pump body. From the pump the oil is forced through copper tubes to the crank shaft main bearings and the gear case at front of motor.

An oil pressure regulating device is attached to the oil line in the crank case. This maintains a constant pressure by releasing the surplus oil which flows over the timing gears and back to the reservoir. There is provision on the oil pump for making connection with an oil pressure gauge on the dash board.

Other bearings are lubricated by the splash system. Catch basins are provided above each cam shaft in which oil from the splash is trapped and fed to the bearings through a suitable passage. Below each connecting rod is a trough into which the oil drains from the crank shaft bearings and from which point it is picked up by the connecting rod dippers and thrown over the interior of the motor.

On the side of the motor, at the rear end, will be found a combined oil filler and breather, a device for relieving the crank case compression. A cast aluminum oil pan bolts to the bottom of the crank case. The pan contains the lubricating ail ond screens which prevent foreign matter from being pumped through the oiling system. On the side of this reservoir is an indicator, which shows the quantity of oil in the motor. Oil capacity is approximately two and a half gallons.

How to Tell When to Drain Crank Case.—If oil is thick or black, unscrew the drain plug in bottom of crank case oil well. The oil strainer is removed by unscrewing the plug which holds the strainer in place. The strainer comes out with the plug. Clear with gasoline, and pour kerosene in breather pipe until same runs reasonably clear. Oil strainer is removed by unscrewing the plug which holds the strainer. Pour one gallon of kerosene into breather pipe, and run motor slowly for one minute. Completely drain out kerosene and refill with oil. This should be done every five hundred miles.

Note to Instructor.—Have student explain every step, and point out proper places on engine. Describe journey of oil through lubricating system.

When two parts of a mechanism rub together, it is necessary to use some means of preventing excessive friction, and this is usually done by applying lubricating oil between them. Without a lubricant the friction causes heating and the result is cuts or scratches on the surface of the two parts.

Two parts intended to rub together, like a shaft in its bearing, should be made as smooth as possible for roughness causes friction which lubrication cannot prevent. The more rapid the movement of the parts against each other and the greater the pressure, the more they must be lubricated; but as some move much more than others, and are subjected to greater strain and pressure, the kind of oil or lubrication must be varied to suit just these conditions.

Engine Lubricating Systems.—The principal parts of the engine to be lubricated are: Main shaft, cam shaft, crank pin and wrist pin bearings, cylinder walls; piston and piston rings; valves and push rods. Methods of lubrication of engines may be divided into two general classes: The circulating and the non-circulating systems.

The circulating systems are systems having a continuous circulation of oil and are frequently called the pump-systems. For instance, a system using a force pump for pumping the oil from the lower part of the crank case to the

upper part, with a drain to the lower part again, is termed a circulating system.

A non-circulating system is a drain or gravity system, or a mechanical feed with so many drops per minute, depending upon the speed and size of the engine, with no provisions for circulating the oil again. These systems may be, and are frequently, combined, for instance, the combination of force feed and splash systems. But generally speaking, the systems can be grouped together under (1) splash and (2) force feed lubrication.

Drop or gravity feed and splash: The non-circulating system consists of a drain or gravity feed oil cup placed over the bearings and also on the side of the cylinder. Special oil cups are required for the cylinder, which do not permit the compression interfering with the oil entering the side of the cylinder wall. The oil drips by gravity and the surplus flows to the oil trough, where it is picked up by the connecting rods and splashed to the parts above. The oil in the lower part of the crank case is kept at a sufficient level for the connecting rod to pick it up and splash it. The filling is done once in a while as required by hand. The oil cups feed by drops and usually the manufacturer determines how many drops per minute are required. The oil flow is not controlled by the engines and each drop is therefore provided with an adjustment whereby the feed may be regulated when the engine is running or turned off when it is stopped. This is classed as a non-circulating system.

This system is used extensively on two cycle marine engines and on stationary engines. Two cycle engines are also lubricated by mixing oil with the gasoline through the mixing valve, the mixture being about one pint of oil to five gallons of gasoline. This system for automobiles, however, may be disregarded.

The two splash system alone is non-circulating. The crank case is made oil tight, and oil is splashed in it to such a depth that the bottom end of the connecting rod dips into the oil, and splatters it to all parts of the crank case and the bearings and the lower part of the piston. An oil groove is sometimes cut around the lower part of the piston and the oil splashing in this is carried upward and distributed on the cylinder walls and rings. There are no oil troughs in this system. As the oil is used, more must be added to the crank case to keep the necessary level. This is done: (1) by means of a hand pump connecting the crank case to an oil tank, or (2) by an oil cup that drips a certain amount of oil into the crank case every minute, or (3) by filling through a breather pipe. The pipe is connected to the crank case. The opening is closed by a cap, which does not fit tightly and allows air to enter, but prevents oil from working out. With the hand pump the driver gives a stroke or two every few miles, experience being his guide as to how often and how much. This latter system, however, is not much used on automobiles, but is extensively used on motorcycles. It is termed a non-circulating system.

The objections to the splash system are as follows: While the engine remains level the splash system gives fairly good results, so long as the level of oil is kept up to the lowest point of the connecting rod where it can be picked up and thrown to the upper parts. If, however, the car is in such a position that the engine is tilted, then the oil goes to the rear of the cylinder. The rear cylinder is over lubricated and the others are often under lubricated. Even though a baffle plate is placed in the crank case still there is one cylinder minus oil. Therefore some other means must be employed so that all cylinders receive their proper share of oil.

One method overcoming this latter mentioned objection is to provide troughs under each connecting rod, as in the case with the Ford engine. The troughs

retain the oil, even though the engine is at an incline. The need is to keep the oil at a constant level in the troughs. This is accomplished by some means of circulating the oil. In the Ford engine the flywheel is run in oil and drives the oil through a tube to the timing gears, thence back to the crank case.

Splash System Circulating.—This system could be termed a circulating splash system, also a pump over system. It is the true constant level circulating splash system because the oil troughs are kept at a constant level by a circulating pump.

The operation of this circulating or pump-over system of oiling is as follows: The main oil supply is contained in a reservoir under the troughs, from which it is drawn by a pump, and forced through pipes which lead to a point above the main crank shaft bearings. Thence it is forced down on to the bearings. The overflow from these bearings is forced against the walls of the crank case and cylinders and as it is run down it is collected by inclined channels, which conduct it to the troughs under the connecting rods. For the lubrication of the connecting rod bearing, scoops are fitted to the lower ends of the connecting rods. They dip into the oil contained in the troughs and scoop it up into the crank pin bearings at the lower ends, and also through tubes running up the connecting rods to the piston-pin bearings (wrist pin bearings). Overflow pipes are provided in the trough so that excess oil can return to the reservoir.

The pump is usually a gear type of pump operated by bevel or spiral gears and vertical shaft from the cam shaft. On many engines the pump is a plunger type operated by a cam on the cam shaft.

The depth of the oil in the splash system should be just enough, so that the splash distributes the oil.

In a full force feed lubrication system, the oil is forced by a pump from an oil reservoir, usually cast to the bottom of the crank case, called an oil pan. The oil is forced to the main bearings and on up, channels for pipes to the wrist pins; out the wrist pin to the walls of the cylinders. This is the true circulating system of the force feed type.

Kind of lubricating oil to use. At present time most lubricating oils are straight mineral oils made from different distillates of petroleum. A good grade of gas engine oil is necessary because the flame inside of the internal combustion type of engine burns the oil, leaving nothing for lubrication, hence causing wear. Therefore, nothing but a high fire test oil answers.

All oil should be removed from the engine every 500 miles of running; but the practice of throwing this oil away is wasteful and costs the automobile world a great deal of money through the erroneous idea that this oil has ceased to be useful. It is just the oil necessary to mix with a grease to form a gear lubricant.

Do not start the engine under its own power after new oil has been put in, without first turning it over several times with a starter or by hand; this is done to eliminate all kerosene used in washing out the engine. This action pumps the engine oil in its proper channels before it is run on its own power.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

LUBRICATION

LECTURE II

LUBRICATION TROUBLES

(*a*) Discussion of different grades of oil to be used on different parts of truck.

These lubricating mediums should each be used where they are best adapted. An oil that is suitable for one part of the mechanism may not be suited for another part. Only mineral oils should be used in gasoline engine cylinders, as they alone meet the requirements. For this reason the oils used for steam engine cylinders are not good for gasoline engine use, as they do not withstand the high temperature which rises in the gas engine cylinder. There are two main requirements for good cylinder oil. It should have a high flash point, that is, it should not break down and give off inflammable gases at low temperatures; and, second, it should retain its body and not become so thin that it is worthless as a lubricant at high temperatures. It should have sufficient body to maintain a positive film between piston and cylinder, yet should not be so heavy as to retard the free motion of the piston and rings. It should also be free from acids or any form of vegetable or animal matter.

(*b*) Lubrication of clutches, universals joints, and ignition system.

The multiple-disc type of clutch is the only one in which any lubrication should be used, and the oil here should be drained off about every 1,000 miles, the clutch well cleaned out with kerosene, and then filled with light machine oil, the amount, of course, depending upon the capacity of the case. All clutches that use and kind of facing, such as asbestos, raybestos, or leather, should never be lubricated, as the oil decreases the friction and causes slipping. Clutch leathers will retain their life and softness better if given an occasional treatment of neat's-foot oil and then wiped dry.

The planetary transmission system in the Ford automobile is encased so as to revolve in an oil bath.

The splash system is used in the Ford engine. The oil is poured directly into the crank case until it comes above the lower oil cock. The level of the oil should be maintained somewhere between the two oil cocks. The flywheel runs in the oil and picks up some of it and throws it off by centrifugal force; some of the oil is caught in a tube and carried to the front end of the crank case where it lubricates the timing gears. As the oil flows back to the rear part of the crank case, it fills the small wells in the crank case under each connecting rod. As the connecting rod comes around, a small spoon or dipper on the bottom scoops up the oil, so that there is a regular shower of oil all the time. The pistons, cylinder walls, and bearings are lubricated in this manner and the oil is kept in continuous circulation. All parts of the clutch and transmission are lubricated in the same manner as the engine.

The oil level should never get below the lower oil cock and should never get above the upper oil cock. Never test the level of the oil when the engine is running.

There are five places to lubricate the Delco System. No. 1—The grease cup for lubricating the generator clutch. No. 2—Oiler for lubricating the generator clutch and forward armature bearing. No. 3—The oil hole for lubricating the bearings on the rear of the armature shaft. This is exposed when the rear end cover is removed. This should receive oil once a week. No. 4—The oil hole in the distributor for lubricating the top bearing of the distributor shaft. This should receive oil once a week. No. 5—This is the inside of the distributor head. This should be lubricated with a small amount of vaseline, carefully applied two or three times during the first 2,000 miles running of the car, after which it will require no attention. This is to secure a burnished track for the motor brush on the distributor head. This grease should be sparingly applied and the head wiped clean from dust and dirt.

(*c*) Further discussion of greasing.

Where to look for trouble in lubrication systems. But little trouble will be experienced with the constant level splash system in which the oil is circulated by a positive pump through passages cored in the motor base instead of long external pipes. Considerable trouble is experienced on the old style cars having a large number of individual leads running from a mechanical oiler or compression feed oiler to the various bearing points. The simple sight feed lubricator employing compression to cause the oil to circulate from the tank to the manifold fittings indicates a clogged pipe in a positive manner as the oil drip feed glass will fill up if the pipe is constricted for any reason. In event of the failure of the oil to drop in the sight feed glasses when the adjustment screws are loosened to supply more lubricant, the various pipe connections should be examined. The first one to look at is the pressure pipe running to the tank. The first essential is to make sure that the tank filler cap seats securely, and that the leather washer is interposed as packing under the cap. Disconnect the pipe next to the check valve and with the motor running note if there is any pressure, i. e., if impulses from the exhaust can be felt on the hand. If not, the nipple of the exhaust manifold or pipe should be removed and cleaned as it may be choked with carbon, especially if considerable oil is fed to the motor. The check valve near the tank may also be fouled up, due to foreign matter. The check valve should be taken apart and cleaned, replaced, and the engine again started for testing the pressure. A simple method of quickly locating the fault in a system of this kind is to disconnect the pressure pipe at the tank and blow through the check valve member. If the tank and oil pipe connections are tight, the oil will flow through the sight feed glasses, and it will be apparent that the trouble is due to not enough pressure being supplied the tank.

Leaks may exist between the sight feed glasses and their holders, and this is usually denoted by leakage of the lubricant around the bottom of the glass. In disassembling and readjusting this member, care should be taken after new packing washers have been replaced, when readjusting, not to screw down the fittings against the glasses too tightly as the glasses may be broken. When the glass fills up with lubricant, which is a sure indication of a clogged feed pipe, that member should be removed and thoroughly cleaned by a compressed air blast or steam under pressure. The steam is to be preferred as it will heat up any solidified wax or grease in the pipes. These sight feed glasses are apt to accumulate dust and dirt, especially as they are mounted in an exposed position for the driver's convenience. For removing dirt with a cloth when the parts are difficult of access, and this is especially true when the sight feeds are assembled in a manifold fitting, where they are placed directly on the dash, a coarse, soft string is used, a couple of turns being made

around the glass. By imparting a sawing motion to the ends of the cord the encrusted deposit will be easily removed.

In those lubricating systems having individual leads running from a mechanical oiler, if failure of oil to reach the bearing is not due to a broken or constricted feed tube, the trouble must exist at the pump applying that member. The common fault in plunger pumps is failure of the check valves to seat properly, this being due generally to dirt in the oil. Of course, if the main driving means fails, the pumps will not move and no oil will be circulated. Oil pumps are not so apt to wear out as water pumps on account of the lubricating properties of the oil, which tends to minimize depreciation by keeping friction at a low point.

(*d*) Use of manufacturer's lubricating chart.

DIRECTIONS FOR LUBRICATION

Every Day Car is in Use, or Every 100 Miles.

PART.	QUANTITY.	LUBRICANT.
Crank case.	Keep oil at level of top try cock.	Motor oil.
Steering knuckle grease cups.	One complete turn.	Cup grease.
Steering cross rod grease cups.	One complete turn.	Cup grease.
All spring bolt grease cups.	Two complete turns.	Cup grease.
Speedometer driving gears.	One complete turn.	Cup grease.
Eccentric bushing of steering gear.	10 or 15 drops.	Motor oil.
Wheel hub oilers.	10 drops.	Motor oil.

Twice a Week, or About Every 200 Miles.

PART.	QUANTITY.	LUBRICANT.
Fan hub bearing.	Few drops.	Motor oil.
Pump shaft grease cups.	Two complete turns.	Cup grease.
Steering gear case oiler.	Fill.	Motor oil.
Steering gear case grease cup.	Two complete turns.	Cup grease.
Steering wheel oil hole.	8 or 10 drops.	Motor oil.
Steering column.	10 or 15 drops.	Motor oil.

Every Week, or About Every 300 Miles.

PART.	QUANTITY.	LUBRICANT.
Spark and throttle shafts.	Few drops.	Motor oil.
Control bracket bearings.	Thoroughly.	Motor oil.
Transmission case.	Enough to cover lower shaft.	Motor oil.
Pedal fulcrum pin.	Thoroughly.	Motor oil.
Brake pull rods and connections.	Thoroughly.	Motor oil.
Brake cross rod grease cups.	Two complete turns.	Cup grease.
Torque rod grease cups, front and rear.	Two complete turns.	Cup grease.
Brake shafts on rear wheels.	Thoroughly.	Motor oil.
Rear spring perch grease cups.	Two complete turns.	Cup grease.

Twice a Month, or Every 500 Miles.

PART.	QUANTITY.	LUBRICANT.
Magneto bearings (3 oil holes).	3 or 4 drops.	High grade light machine oil.
Dynamo drive shaft universal joints.	Fill one-half full.	Cup grease.

Every Month, or Every 1,000 Miles.

PART.	QUANTITY.	LUBRICANT.
Crank case.	Drain off dirty oil; clean oil screen at left of motor thoroughly; fill to level of top try cock.	Motor oil.
Reach rod boots.	Pack thoroughly.	Cup grease.
Spring leaves. (Jack up frame and pry leaves apart.)	Thoroughly.	Graphite grease.
Hub caps.	Pack thoroughly.	Cup grease.
Universal joints.	Remove grease hole plug and fill one-half full.	Cup grease.
Gasoline pressure hand pump.	4 or 5 drops on leather plunger.	Light machine oil.

Every 2,000 Miles.

PART.	QUANTITY.	LUBRICANT.
Differential housing.	One-half full.	Special axle compound.
Transmission case.	Drain thoroughly, flush with kerosene, refill to cover top lower shaft try cock.	Motor oil.

Dynamo should be lubricated every 3,000 to 5,000 miles.

When changing tires, put a few drops of oil on inside sliding ring of demountable rims to insure easy detaching.

(*e*) Proper use of grease cups and oil wells.

The lubricant is drawn from the oil base through a fine mesh screen, and forced direct to the three main bearings from which it overflows to the oil pan. Six wells in the oil pan directly underneath the connecting rods are supplied with oil constantly, and a constant level is maintained at any motor speed and under all conditions of road travel. The lower end of each connecting rod is supplied with an oil dip which scoops oil directly to the connecting bearings and splashes the lubricant on the piston walls and wrist pin bearings. The overflow from the front main bearings flows to the front timing gear. From there it is carried by gravity to all gears on the secondary shaft. It is very important that the oil strainer be kept clean so that the circulation of the oil be insured. For this reason the removal of the oil strainer has been made easy. By loosening the four stud nuts on the bottom of the crank case the oil screen may be withdrawn and cleaned by dipping it in a pail of gasoline.

In replacing the screen it is well to shellac the gasket between the strainer flange and crankcase to make sure that the lubricant is properly retained. A drain plug is also provided in the bottom of the crank case for draining the lubricant. This should be done once every thousand miles. The crank case should then be washed out by pouring kerosene into the breather pipe. After the kerosene has been removed, replace the plug, and refill the system by using the old lubricant, being careful to strain it through a fine grade of muslin, and add fresh lubricant to make up the proper amount.

The proper working of the system is indicated by a pressure gauge located upon the instrument board of the cowl dash of the car in plain view of the driver. It is not necessary that this gauge indicate a given amount of pressure in pounds; it will be sufficient to notice the slightest indication of pressure by the needle moving to the right when the motor is accelerated. For motor lubrication use a light cylinder oil, free from carbon and having a flash-point of not lower than 425, and a fire-point of not less than 475 degrees Fahrenheit.

Another forced feed system in which no reliance is placed on splash feed due to the connecting rods dipping the lubricant, is used on some Pierce-Arrow six-cylinder motors, and includes the novel feature of having the oil supply drawn from the oil container at the bottom of the crank case to an oil reservoir carried above the cylinders. While the oil is supplied to the reservoir by the pump, it flows to the bearing points indicated by gravity through oil supply tubes of large size. Both the oil reservoir and the bottom of the crank case are inclined twenty-five degrees, this inclination being given to the oil reservoir, so that when the car is on a hill the oil will still circulate. There are eight of these leads at the bottom of the oil reservoir, one leading to the timing gear compartment of the crank case, the others to the main bearings of the crank shaft. The connecting rods are lubricated through suitable drilled passageways in the crank shaft. As is true of other systems of

this nature, the interior of the engine base is filled with an oil mist all the time that the engine is in operation, this mist serving to lubricate the piston, cylinder walls, and valve operating mechanism.

The simple pressure feed system used on the National car is such that the bottom of the crank case serves as a main reservoir for the lubricant. It is drawn from this by a geared oil pump driven by bevel gearing from the cam shaft, the discharge from the pump being piped to an indicator gauge on the dash. The return from this indicator is directed to a conduit running the length of the crank case which supplies the oil to the compartments into which the connecting rods dip to splash the lubricant about the crank case interior. Attention is directed to the oil wells or pockets above the main bearings which catch part of the oil distributed by the connecting rods and which feed it to the main crank shaft bearings.

Another example of the system in which the oil is forced to the main bearings and from these members to the crank-shaft interior which is used on the Marmon motor, operates in the same manner as the Pierce-Arrow system, except that all of the lubricant is carried in oil reservoirs attached to the bottom of the crank case. On some engines, especially of the Knight sleeve-valve form, it is desirable to increase the oil supply as the engine speed increases. This may be easily done, by providing swinging oil troughs operated by linkage, which is interlocked with the carburetor throttle actuating lever. When the supply pipes used to fill the troughs, and the rod employed to tilt the trough, are in the higher level position the connecting rod will take out more oil on account of the higher level. This position is used only on the highest motor speeds. On the intermediate speeds not as much oil is required as when the engine is running fast, therefore the troughs are tilted to a point where the oil level will be reduced. This system has the advantage of preventing smoking due to burning too much oil, as in those systems where immovable troughs are employed the level of the oil in these members must be kept high enough to supply positive lubrication at high motor speeds. Obviously, this amount of lubricant may be too much for lower engine speeds, and the surplus lubricant will be discharged through the exhaust in the form of smoke.

Motor Truck Company Drivers' Course

LUBRICATION

LECTURE III

SPECIAL LUBRICANT

The most satisfactory lubricant for the sliding gear transmission is a heavy molasses-like mineral oil. This has a property of following the gear teeth and maintaining satisfactory lubrication, and the gear teeth do not cut tracks in it as they would in hard grease. Metal particles which are worn from the gear teeth when the gears clash, sink to the bottom and do no harm if the transmission lubricant is semi-fluid, but if hard grease were used, the particles would be carried between the gear teeth or into the ball or roller bearings, causing wear, noise and possible even breakage.

When the case is filled, the manufacturer's instructions concerning depth and quantity of lubricant should be followed. In general it is necessary that the oil come up at least to the bottom of the lower shaft so that all gears will be properly lubricated. In addition, if the case is filled to the top it is almost certain that the oil will work out past the bearings. Packing rings are generally provided on the shafts to hold the grease and exclude sand and dust.

Every two thousand to five thousand miles, as recommended by the manufacturer, the lubricant should be drained from the gear case and the case flushed out with kerosene and refilled.

In filling the gear set, put in the lubricant to a depth about half the height of the gearbox. That is, have it come about even with the center of the main shaft, this will completely submerge the countershaft in the average gearset design and will bring the under face of the main shaft gears into the lubricant. It is important in this connection to see that the packing rings are tight and prevent leakage where the drive shaft emerges from the gearcase and where the shaft from the clutch enters it. If there is leakage here, it not only will act as a collector of dirt and dust, but the gears will be robbed of their proper lubrication.

Lubrication of Differential

The differential housing should hold the lubricant in the rear axle gears, so that attention is needed only as stated above, but sometimes a disagreeable looking rear axle is noticed where the oil or grease oozes out through cracks or leaks in the rear cover plate or through the axle tubes on to the wheels. This is not so common a fault as it used to be when axles were not designed so well to trap the oil and keep it where it belongs. However, an occasional careless driver will let his axle get in this condition by not having a proper gasket between the differential housing cover plate and the housing itself. It is not much trouble to cut a gasket if the old one gets worn or out of shape, and it saves the brake bands which often become oil soaked and slip.

The Axle.—In some cases, a heavy transmission oil is recommended for the axle but in most instances it is best to use either a semi-fluid grease or even a heavy grease. There is less chance for the gears to throw these, and the space is smaller so that it is next to impossible to give any fixed rule for rear

axle lubrication. There are so many designs, and where a heavy oil or a grease will work satisfactorily in one instance, some other form is better in another. Lubrication is probably the most important detail in connection with the care of the rear axle. To insure effective lubricating of the driving gears the differential mechanism in the rear axle housing should be kept filled to such a depth that the driving gear will dip an inch or an inch and one-half in heavy mineral oil about the consistency of molasses (similar to 600 W). This will follow the gears as compared with hard grease in which they might cut tracks. Particles of metal worn or chipped from the corners of the gear teeth will sink to the bottom of this heavy oil whereas with grease they might be carried in suspension into the gear teeth and bearings where they would cause noise, wear or even breakage.

Stiff grease should never be used in the rear axle housing if it is tight enough to hold a heavy molasses-like oil or a light bodied grease.

The rear axle housing should never be filled with a lubricant to a greater depth than that recommended by the manufacturer in his instruction book (sometimes indicated by high level drain plug).

The use of a small amount of finely divided flake graphite mixed with a heavy oil or light grease in a bevel gear rear axle is often recommended by the manufacturer.

The grease cups and oil cups on various points of the rear axle assembly such as on the brake shafts, springs, saddles, torsion and radius rods, etc., should be filled continually.

The differential case should be drained, flushed with kerosene and refilled every 2,000 to 5,000 miles as recommended by the manufacturer.

Note to Instructor

Give class practical use of the manufacturers' oiling and lubricating charts.

Results of Improper Lubrication

When the transmission is not kept filled with lubricant, great friction results when the gears are in mesh, causing them to crystalize and bevel over, also the transmission bushings become worn egg-shaped, throwing them out of alignment, which causes the transmission to grind and makes it hard to shift.

Results of improper lubrication in differentials are the same as in transmission only that there are more parts to be worn out.

Motor Truck Company Drivers' Course

LUBRICATION

LECTURE IV

GEARS AND WHEEL HUBS

Methods of Retaining Lubricant in Wheel Hubs and Differential Housings.—The retention of lubricant and exclusion of dust is one of the problems confronting the designer of automobile axles that can be solved in a number of different ways. It is important to prevent the escape of grease from the differential housing because it will accumulate on the brakes and reduce their efficiency. While it is difficult to overcome leakage due to an excessive supply of lubricant, if reasonable precautions are taken in this respect, an axle housing may be made practically grease tight. A number of oil-retaining methods selected at random and known to give satisfactory results in practice are depicted in accompanying series of illustrations.

A worm gear drive axle is apt to lose oil because this form of gearing demands more lubricant and of a more fluid nature than that ordinarily supplied to bevel gear driven axle housings. An ingenious application of a self-tightening stuffing box is used in the construction. The tubular housings that enclose the live axles project into the differential case and have an enlargement at the end closed by a packing retention nut. This bears against one wedge-shaped graphite packing which fits the taper seat of the other packing element. Since a certain amount of wear is unavoidable as the shafts revolve inside the packings, some method of keeping the packings properly seated is necessary. This is accomplished by a coil spring which holds the packings in intimate contact with the shaft. When the car rounds a curve and the lubricant is thrown to one side, the space between the sleeve tube and housing acts as a pocket and retains the oil, allowing it to flow back to the bottom of the housing when the car is no longer tilted.

In a number of cases, felt washers form an effective barrier against passage of oil along the shaft, though when these are employed, a supplementary packing member is utilized at the wheel end of the axle. Two felt washers firmly held between steel clamping plates may be fitted, or a special composite member may be substituted. The packing member is inclined as shown, so that the oil carried around by the axle will be deflected back to the bearing housing.

The self-adjusting stuffing box arrangement is similar to transmission stuffing boxes, except that more felt washers are used and metal wedges are depended on to keep the washers bearing against the axle. As in other designs, the pressure of a substantial coil spring keeps the metal wedges in firm contact with the felt packings.

There is no better known or more effective method of keeping oil from leaking out of the axle at the wheed end than the patented oil slinger invented by Weston-Mott engineers. The function of this member, which revolves with the wheel, is to throw the oil which leaks by the felt washers into an oil catch basin cast integral with the brake-band carrying plate. A bent pipe at the bottom of this chamber allows the oil to drain off to the ground, clear of the brakes and tires.

The method shown involves the use of a tapering axle housing tube and a bearing retention nut carrying a liberal felt washer in an annulus machined therein. The construction is a combination of felt washer to restrain the oil and a catch-basin to hold any lubricant that escapes past the felt packing. The oil container is attached to the casting used to support the brake assembly. This system is used by the Salisbury Wheel & Manufacturing Company.

The methods of grease retention shown are similar to those previously described. A simple oil retaining ring and felt packing are believed sufficient. We have a modification of the idea in which a more liberal felt washer is used, which is held in a pressed steel retaining member. The stuffing box idea is more often used on transmission gear cases than on rear axles, but as the gear case is sometimes combined with the differential housing a packing of this form may be found on the rear axle. In order to prevent oil leakage it is necessary to screw up on the packing ring to compress the felt more tightly against the shaft. Before the adjusting member can be turned it is necessary to release the locking screw which must be replaced when the stuffing box has been properly tightened. The automatic stuffing box is used on some Overland rear axles. This consists of a substantial felt washer held between steel plates, a constant pressure against the washer being exerted by the coil springs. Other Overland models have the grease packing. This is the form of stuffing box widely applied in marine use, which must be taken up from time to time to compensate for wearing of the felt packing member. If grease escapes from the end of the axle shaft and accumulates on the wheels or the tires, this may be taken as a sure indication that the felt packing is worn and must be replaced with new washers. It is not only desirable to keep the grease in the axle on the score of cleanliness, but also on that of economy of lubricant.

Lubrication Adjustment and Care.—All steering connections from the column forward to and including the tie rods and the steering knuckles should be lubricated daily. The ends of the reach rods, knuckle pins and parts which are subject to vibration and wear should be given careful inspection frequently.

The worm and gear or screw and nut which are housed in the base of the steering column should be lubricated by keeping the casing filled with a heavy oil or packed with a soft grease and should have a few drops of oil added from time to time according to the instructions of the manufacturer.

The ends of the steering reach rod are sometimes packed with grease and covered with a leather boot instead of being provided with grease cups.

Proper alignment of the wheels and proper lubrication and care of all steering connections will make the difference between easy and difficult steering. The necessary attention should not be neglected, as safty depends upon having the steering mechanism always in good condition.

MINOR POINTS FOR ATTENTION. LUBRICATION OF BRAKE, ROAD JOINTS, HINGES, ETC.

Every Week, or About Every 300 Miles.

PART.	QUANTITY.	LUBRICANT.
Spark and throttle shaft.	Few drops.	Motor Oil.
Control bracket bearings.	Thoroughly.	Motor Oil.
Transmission case.	Enough to cover lower shaft.	Motor Oil.
Pedal fulcrum pin.	Thoroughly.	Motor oil.
Brake pull rods and connections.	Thoroughly.	Motor Oil.
Brake cross rod grease cups.	Thoroughly.	Motor Oil.
Torque rod grease cups, front and rear.	Two complete turns.	Cup grease.
Brake shafts on rear wheels.	Two complete turns.	Cup grease.
Rear spring perch grease cups.	Thoroughly.	Motor Oil.
	Two complete turns.	Cup grease.

General Notes on Lubrication.—There is no one thing which is the primary cause of more trouble and the cause of more expense in the maintenance to the mechanism of an automobile than insufficient lubrication.

All moving parts of a car are usually manufactured with a high degree of accuracy and the parts are carefully assembled. In order to maintain the running qualities of the car it becomes necessary to introduce systematically suitable lubricants between all surfaces which move in contact with one another.

The special object of this chapter is to point out the places in the car which require oiling. While it is manifestly impossible to give exact instructions in every instance as to just how frequently each individual point should be oiled or exactly how much lubricant should be applied, we can give this approximately, based on average uses.

It should be borne in mind that friction is created wherever one part moves upon or in contact with another. Friction means wear, and wear will come on the metal itself unless there is oil, and oil is much cheaper than metal. The use of too much oil is better than too little, but just enough is best.

Proper lubrication not only largely prevents the wearing of the parts, but it makes the car run more easily, consequently with less expense for fuel and makes its operation easier in every way.

The oiling charts shown in this chapter indicate the more important points which require attention. But do not stop at these. Notice the numerous little places where there are moving parts, such as the yokes on the ends of various connecting rods, and pull rods, etc. A few drops of oil on these occasionally will make them work more smoothly.

Oil holes sometimes become stopped up with dirt or grease. When they do, clean them out and be careful not to overlook them. Also be careful not to allow dirt or grit to get into any bearings.

Judicious lubrication is one of the greatest essentials to the satisfactory running and the long life of the motor car. Therefore lubricate, and lubricate judiciously.

The auto engine should be lubricated by some means that will insure a definite supply of lubricant to the moving parts and that will supply the loss caused from vaporizing, burning and leakage.

The differential, axle bearings and shift gears are lubricated with semi-solid grease. The rear axle is not oil-tight, and therefore a fluid oil should not be used. Semi-solid lubricants also help to cut down the noise and wear where the pressure is heavy, and have sufficient cushion so that they adhere to the gear teeth. The lighter oils are better adapted for the high speed close-fitting parts. Other moving parts may be lubricated with the ordinary oil can, but are generally lubricated by the compression cup system. These cups may be screwed up from time to time to add more lubricant to the bearing surfaces.

The transmission should always contain sufficient lubrication to bring it up to the level of the drain plug on the side of the case, or so that the under teeth of the smallest gear will enter to their full depth.

The differential case should contain enough lubricant to bring it up to the filling hole, or should be about one-third full.

Wheel bearings should be packed with a thin cup grease. Do not use a heavy grease because it will work away from the path of the roller or ball and will not return. In each hub there is usually a small oil hole. Inject some engine oil here whenever you are oiling the car. It will keep the grease soft

and in good condition. Before lubricating any part, wipe all dirt from it so that the dirt will not get into the bearings.

The steering gear is perhaps one of the most important parts of the car to keep properly lubricated. Failure of the steering apparatus is a dangerous thing and a few drops of oil given to the oil cups and the various steering connections constitute a cheap and safe means of avoiding accidents. Most types of steering apparatus are packed with grease which, having no outlet, will remain. However, the grease will become dry and a little oil should be added from time to time.

Few motorists think of lubricating their brake connections. Mud and water will find their way into the brake mechanism and a squeeze of the oil can and a turn of the grease cups given daily will keep them in good working condition.

The principal engine lubricating systems can be grouped under the following heads: First, splash system; second, splash with circulating pump, which may be either a "forced feed" or a "pump-over" system; third, full forced feed; fourth, mixing the oil with the gasoline.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

CLEANING, OILING AND INSPECTION

LECTURE 1

GENERAL DISCUSSION

At the command, Prepare for Inspection, men will line up at attention, driver at right and assistant driver at left of truck. Upon whistle signal by Truckmaster, the men will perform the following duties in the order given, in a military manner.

1. *Cleaning Entire Truck.*

Driver is responsible for condition of entire truck, but personally cares for the Power Plant, including—

1. Engine proper
2. Cooling System
3. Carburetor
4. Ignition
5. Generator
6. Dash Instruments
7. Engine Controls

Assistant Driver is responsible for—

1. Clutch
2. Transmission
3. Drive Shafts
4. Rear Axle
5. Rear Springs
6. Brake Mechanism
7. Rear Wheel
8. Front Axle
9. Front Springs
10. Front Wheels
11. Hood
12. Fender
13. Body

Note.—All grit, sand and mud must be thoroughly removed from all moving parts.

2. *Lubrication Schedule.*

Number of places given for Liberty Class B trucks, other trucks in proportion.

DAILY

1. Fill crank case to proper level.
2. Fan bearing oil, one grease plug.
3. Water pump, heavy grease, two cups.
4. Starting crank, one grease cup.
5. Grease steering connections, four grease cups.
6. Grease steering knuckles, two oil plugs.

7. Oil spark throttle rod sockets and joints, thirteen places.
8. Clutch bearing trunion, one oil plug.
9. Clutch case bearing, one oil plug.
10. Oil spring shackles, eight oil wells.
11. Oil brake rod clevises, twenty clevises.
12. Oil wells on equalizer and intermediate brake bars, six wells.
13. Grease cups on rear axle brake shaft, eight cups.
14. Oil brake shoe equalizer pine, sixteen, eight for each rear wheel inside brake drum.

WEEKLY

1. Drain oil from crank case, wash out with kerosene, refill to proper level.
2. Wheel bearing grease, all four wheels.
3. Grease steering gear case, one plug.
4. Transmission, fill to level.
5. Fill universal joints, four.
6. Differential, fill to level.
7. Two drops oil in magneto, two places.
8. Two drops oil in generator, two places.

Notes:

Use only clean new oil.

Do not fill self oiling wells on Liberty Trucks higher than ¼ in. below top of wick tube.

Turn up all grease cups until grease feeds through freely.

This forces out all dirt from bearings. Wipe off all excess oil and grease. Refilled grease cups must be given at least three turns.

3. Inspect radiator, gasoline tank, and all reserve tanks provided, to make sure they are properly filled.

Inspect complete equipment and report breakage, shortage and repairs needed to Assistant Truckmaster.

1. Tools.
2. Supplies.
3. Equipment.

4. As soon as these duties are completed the driver will report to Assistant Truckmaster immediately.

5. Truckmaster and Assistant Truckmaster should pass around trucks during this procedure and see that the work is being done properly.

6. Assistant Truckmaster should report to Truckmaster as soon as all trucks in his section are ready for inspection.

7. Truckmaster calls company to attention, receives reports from each section verbally, makes notes on condition, breakage, shortage and repairs needed on each truck. Then upon orders of Company Commander dismiss the company.

It may be well at this time to say that the body and running gear should be washed down thoroughly at every opportunity especially where soft mud is on the wheels or metal parts, owing to the fact that if this mud should be allowed to become hard it is very much more difficult to remove. It is not alone important to remove that mud which is visible but the man washing the car should climb in and about every conceivable place that this dirt could possibly accumulate. At times it will be necessary to remove greases, road oils,

etc., with gasoline. It is very easy for an inspector who is thoroughly experienced to locate almost instantly those parts which have been neglected. After the car has been thoroughly cleaned the different units that we mentioned a short while ago are thoroughly cleaned using kerosene and air if possible or whatever cleaning materials that are on hand under the circumstances. The engine should be thoroughly washed down removing all grit and sand from not only the moving parts but others also. All parts that are plate or metal finish should be retained to that standard. The electrical instruments and other important motor auxiliaries such as the carburetor, etc., should be thoroughly cleaned in the same manner. The other units, particularly the clutch, transmission, drive shafts, rear construction, springs, brake mechanism and wheels should receive that attention which will enable them to function properly and therefore eliminate the unnecessary replacement of parts and incidentally prolong the life of the car. The daily and weekly schedules are to be followed closely and it is the duty of the inspector to see that all grease cups are well filled as often as prescribed. If the proper lubrication of the car is followed in detail, there will be no necessity of oil running out through the rear construction onto the brakes which in many cases is responsible for accidents, and I could mention a number of other cases where too much oil is almost as bad as none at all.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

CLEANING, OILING AND INSPECTION

LECTURE II

GENERAL DISCUSSION—(*Continued*)

In order that you may have a bird's-eye view of the repair system as operated in France, I will outline to you the repair system showing the different parts and establishments, which start with the company near the Front line and end up with the Reconstruction Park, which is the factory for the A. E. F.

Attached to each company is a light repair truck on which is a standard stock of tools and parts, made up of ten days' supply of spark plugs, nuts, bolts, valve springs, brake lining and the minor parts needed in quick repairs; also a fairly complete assortment of hand tools. That stock is kept up by requisition every other day on the next larger unit, which is the Service Park. The stock on hand, plus the requisitions going through channels, should equal the standard unit equipment list of that truck at all times, and the company mechanic should never allow that equipment list to get down.

The next step in the chain is the Service Park. A Service Park is a mobile machine shop unit with a personnel of 35 men and an officer. This personnel is made up of the different trades. There is a radiator man, chassis man, engine man, electrical man, tire man, and so on. The Service Park keeps on hand at all times a ten day supply of larger parts (not assemblies) such as connecting rods, bearings, bushings, brake linings, etc. A Service Park is supposed to take care of the repairs on 148 trucks, and a proportionate number of passenger cars and motorcycles, and can handle repairs on six trucks at one time in the park. The unit equipment list for a Service Park is laid down in bulletins and consists of a definite number of bearings, connecting rods, bushings and parts for all the vehicles whcih it serves. No repairs are attempted in a Service Park that will require more than ten days to complete.

The next link in the chain is the Overhaul Park. The Overhaul Park is a much larger unit and may consist of any number of men. We have a system of repair sections, groups and units. The section is the smallest and consists of 77 men and 3 officers. By grouping together 4 sections and a headquarters we make a repair group. By grouping together 4 groups and a headquarters we have a repair unit. We can make an Overhaul Park of any size we want. We can take one section of 77 men and 3 officers and make that an Overhaul Park, or take 4 sections and call it a Repair Group and make that a larger Overhaul Park or take 4 groups and make it our largest unit, which is the Repair Unit, and consists of 1,280 men.

The repairs done in the Overhaul Park are practically all repairs than can be made to the vehicle except reconstruction. If a vehicle is badly damaged by shell-fire or totally wrecked through misuse so that all the working parts will have to be replaced and it is more a question of salvage than repair, that vehicle goes back to the Reconstruction Park and is not touched by the Overhaul Park at all; but, if the work consists of tearing down the motor and rebuilding, tearing out transmissions, rear axles, etc., the Overhaul Park handles it. Assemblies are taken apart here and assemblies are carried in stock as

part of their standard list of parts and supplies for the trucks which they are supposed to serve. Each Overhaul Park can take care of the repairs on 1,800 or 1,900 trucks. It can handle 100 trucks at one time in the park. The Overhaul Park is, of course, farther back from the line than the Service Park. The Service Park is usually within sound of the guns and near the rail head; within reach of the supply and ammunition trains. The Overhaul Park would probably be back 25 to 30 miles from the line and may be more, depending on whether that sector of the Front happened to be active or not active.

Overhaul Parks have quite an elaborate machine tool equipment and can actually make small parts. The time factor enters into all repair work except that done in the Reconstruction Park. No repairs are allowed in a Service Park that require over ten days. If a vehicle in the opinion of the inspector will require over ten days for its repair, it is sent back to the Overhaul Park. If it requires more than 20 days in the Overhaul Park it is sent back to the Reconstruction Park. In that way we do not clog up the Service and Overhaul Parks with a lot of dead material, thereby making it immobile. Mobility must be the first consideration. I might add that an Overhaul Park quite often is an Advance Spare Parts Depot and by an Advance Spare Parts Depot I mean a depot that keeps 30 days' supply of all parts for all trucks operating in the area in which it serves. That includes rear axles, assemblies, transmission assemblies, clutch assemblies, even motor assemblies, and, where it is deemed advisable, a motor is set in and the old motor taken out, repaired later and put back in stock. In fact, repairs of this kind are frequently handled this way; replace assemblies and put the truck into commission, repair the taken out assembly at another time when work will permit.

The next link in the chain is the Reconstruction Park, which is a very large organization. It has a large roofed area and you might liken it to one of our big automobile or truck manufacturer's plants in this country. It is an enormous proposition and when I tell you that for one army alone we have to have upwards of 80,000 vehicles in France you can realize that we have got to have a large factory to look after their repair.

At the Reconstruction Park all reclamation work is taken care of. We call it salvage. All complete overhauls are made there; vehicles come back from all the Overhaul Parks to the Reconstruction Park when the time factor will not allow the Overhaul Park to make the repairs. Broken parts and broken vehicles have to be returned by every member of the A. E. F. for salvage. Even though you think a part is absolutely valueless you are charged with the responsibility of seeing that that part goes back for salvage. The metal in broken parts can be melted up and reshaped into tools; babbitt can be melted and re-used; broken parts can be repaired by careful machine work and by brazing and welding. We also must have broken and worn out parts returned in order to know whether those parts are defective from poor workmanship or material, or worn out through fair wear and tear. This is important, for we must make remommendations for changes in construction on the basis of this information. Broken parts come back through the various parks and establishments to the Base Spare Parts Depot which is in close proximity to the Reconstruction Park. The Base Spare Parts Depot turns the broken parts and supplies over to the Reconstruction Park which reclaims all parts that it is possible to reclaim and then turns them back to the Base Spare Parts Depot for stock. That is the work of the Reconstruction Park. In other words, when you order parts from the Service Park you may not get a new part but you may get a part that has been rebuilt. It is just as good. That system of salvage and the importance of it I will not dwell further on this morning, but will make it the subject of a separate lecture later on in the course.

I will go back now to the company repairs. Company repairs are quite the most important factor in the Motor Transport Service of the A.E.F. If the proper care is not given to lubrication and adjustment and repair work in the company, both in park and on the road it echelons all the way down the line, our Service Parks are overcrowded, our Overhaul Park is overcrowded and our Reconstruction Park is swamped. And really, when you come down to the last analysis there is very little excuse for a vehicle going back from the company to the Service Park except for periodical overhaul and except for damage from shell-fire. If the driver is a good driver, properly trained, if the company mechanic is an iron master as far as upkeep is concerned and is on the job, there will be a minimum of extensive repairs and consequently less work for the Service, Overhaul and Reconstruction Parks. Company repairs occupy the full time of the Company Mechanic and his assistants and a large share of each and every driver's time when not actually at the wheel of his truck.

Company repairs consist of keeping nuts and bolts tight, cleaning spark plugs, trimming solid tires, making minor adjustments to electrical, oiling and cooling systems, cleaning crank case, changing oil and cooling systems, and greasing transmission and differential at proper time. In addition, company mechanics and drivers must report at once parts that show undue wear, breakage and suspected trouble. Where the repairs are beyond the facilities of the company mechanic and the light repair truck the Company Commander should arrange at once that this truck be sent back to the Service Park with all speed. No extensive repairs are undertaken in the company, such as tearing down the motor or any of the other assemblies such as transmission, rear axle, etc. In the first place the company mechanic has not the equipment to do this work and in the second place it would require too much of his time and mean that he would have to neglect minor adjustments and upkeep work on the rest of the trucks, all of which is important.

We will take up next the responsibility of the drivers. There seems to have been a great deal of discussion and some misunderstanding as to how far the driver should be educated in the mechanical construction of his vehicle. Some have said that he should not have any instruction except in driving and that he should be entirely ignorant of the theory and practice of Automobile Engineering. That has not been our experience. On the contrary, we have tried to give the driver every bit of instruction along that line that the time afforded while he was going through school, and if he were there for quite a length of time he kept delving further into the construction and adjustment of the vehicle which he was operating, both the theoretical and the practical, so that when he was through with his training he knew when shifting into first gear, just what was happening in the transmission, and he also knew the difference between a surge in the motor caused by the carburetor being badly adjusted, and a surge due to two cylinders not firing properly. A driver is very often called upon to make minor adjustments himself, under the supervision, if possible, of a company mechanic, but the company mechanic cannot be everywhere at once and the driver has to be able to do these things. The driver is responsible for the proper cleaning of his vehicle. Perhaps that does not sound important to you, but it is *highly important.* We have suffered a great deal of criticism in France in the American Army by the appearance of our trucks. They were not washed, and mud would remain on them for weeks; they were not properly lubricated. Drivers were sloppy in appearance and driving, and very often they would pull up at some Divisional Headquarters alongside a British or a French Headquarters Staff car. The comparison was terrible to look upon. The British or French cars would be as bright as a new penny, although in service perhaps for three or four years. Every bit of brass

and metal was shined up, the frame, the drive shaft and rear axle housing, ordinarily neglected by you and me, were thoroughly cleaned up. You could put your hand on any part of the car. This is why those vehicles are running after four years of service. The cleaning of the vehicles should be done every day. There is one part of the cleaning that can be done every day and must be insisted upon by every Company Commander, non-commissioned officer and mechanic, and that is that the dirt and flinty rock in the dust be cleaned from the spring shackles and all the moving parts of the vehicle. That is absolutely essential, because, if I could go into the spare parts end of it with you, and the troubles we have had, and the troubles we will always have in keeping spare parts in France it would very nearly bring tears to your eyes. We have not had anywhere near a sufficient stock of spare parts for any of the vehicles in France up to the first of May this year. The lack of spare parts is a very serious proposition in France. The proper cleaning of the car will cut down the demand for spare parts tremendously.

The next thing is the lubrication of the car. There are certain things which must be done every day, certain things which must be done at stated intervals, such as every 250, 500, 1,000 and 2,000 miles. You must know the M. T. S. Manual backwards and study up on those things which are to be done at the various periods.

In addition to lubrication, there are other things which must be done at the stated intervals before mentioned. I will enumerate them to you and you will find all of these rules in the Manual.

(*a*) Care must be given to appearance, as well as to the mechanical perfection. See that the body and wheels are cleaned of dirt, and inside of body cleaned out.

(*b*) Be on the lookout at all times for all leaks, and for unusual noises; find the cause immediately and remedy it.

(*c*) In screwing up grease cups always make sure that the grease has actually been forced into the bearing.

(*d*) Never cut out the muffler.

(*e*) Never, under any circumstances, fill the gasoline tank or work on the carburetor in the presence of a naked flame or an oil lantern. If this work must be done in the dark, use an electric torch.

204. After each run. (To be done as soon as truck returns from run.)

(*a*) Fill up gasoline tanks (including reserve supply), oil lanterns, headlights and generators.

(*b*) Drain carburetors. (Much water and other impurities are often found in gasoline.) In freezing weather drain radiators.

(*c*) Remove mud and dirt from places in immediate proximity to joints and moving parts, such as reach rod joints, spring shackles, distance rod hangers or joints, torsion rod joints and springs.

(*d*) After removing dirt turn down grease cups at all places one turn.

(*e*) Examine and tighten all loose nuts, screws, etc., including those of the wood-work.

(*f*) Wash entire truck, if possible.

205. At end of 250 miles:

(*a*) Fill up oil grease cups and see that oil holes are not stopped up.

(*b*) Clean motor and pan under motor; clean spark plug; oil magneto (only drop or two); clean carburetor.

(*c*) Examine clutch; permit no oil on a leather faced clutch.

(*d*) Transmission Case: Fill with lubricant if necessary.

(*e*) Brakes: Examine and regulate tension.

(*f*) Chains: Examine tension.

(*g*) Clean oil strainers.

(*h*) Examine all wiring as to insulation and connections.

(*i*) Go over all nuts and bolts.

206. At end of 1,000 miles:

(*a*) Drain crank case, wash with kerosene, and fill with fresh oil. (Save old oil to return to Service Park.)

(*b*) Jack up body and clean and grease spring leaves.

(*c*) Remove chains, bathe in kerosene, clean with brush, grease and put back.

(*d*) Fill differential with oil.

(*e*) Examine all grease boots and clean and refill if necessary.

I want to caution all of you to be constantly looking for loose nuts and connections and be constantly tightening these things. Our spare parts situation in France will always be a serious one. We will never have as many parts as we need and you will seldom have the supplies and parts when you need them. For this reason, whenever your truck stops to load or unload, or whenever you arrive at the park and have a few minutes, go over your truck very carefully from the front bumper through to the tailgate and see that everything is tight and that no defects or mechanical troubles are liable to hold you up on the road. The Motor Transport Service in France is charged with moving the freight of the A. E. F. We cannot move freight if your truck is out of commission. Troubles corrected before they become serious prevent excessive demands for spare parts, decrease the work of the company mechanics of the Service Park, of the Overhaul Park and of the Reconstruction Park and greatly simplify the maintenance problem. A burnt out or frozen bearing is inexcusable and in France is cause for court-martial proceedings in every case. You will not be able to give any reason whatsoever for trouble of that nature. There is no excuse and none will be accepted. I have been an Inspector of Motor Transportation for several months back in France. I know whereof I speak and I know that the causes of break-downs in the Motor Transport Service were in 7 cases out of 10 due to the inefficiency of the drivers of vehicles. These drivers were not properly trained. They had no conception of discipline before going to France. They were slovenly in their personal appearance. Their trucks were dirty, not properly lubricated, parts were lost off the trucks, thereby tying up that place of equipment for days and sometimes weeks; bearings were burned out, brakes burned out, clutch facing ripped off unnecessarily, radiators smashed, and the vehicles generally not able to handle the freight. The things I have mentioned here if allowed to continue, are nothing short of criminal offenses which at this time deserve the strictest disciplinary action. Both the driver and the company mechanic are responsible for the log-book which accompanies every vehicle in France. This book is issued to the vehicle at the Reception Park at the Port of Debarkation. It stays with the vehicle as long as the vehicle is in service. This log-book is about 4 inches wide and 6 inches long. In it are kept records of transfers of the vehicle and of all repairs made by any repair park. The first page of the book is given over to the specifications of the truck, the engine number, the chassis number, U. S. number, the type and

model of the truck and the detailed list of the equipment which was placed on the truck at the Reception Park. Beginning with the next page there are spaces for the driver to sign for the vehicle and for its equipment and in each case of transfer his signature is witnessed by the signature of the Commanding Officer. The last 3 or 4 pages of the book are given over to records of repairs made. This record shows the number or name of the repair park making the repairs, what the repairs consisted of, what spare parts and supplies were required to make the repairs, and the signature of the inspector or officer entering this data. The information regarding repairs which is entered in this book is invaluable to us at Headquarters as it shows the performance of a truck and also shows the class of repairs that are having to be made on that particular make of vehicles and enables steps to be taken for the correction of defects and changes in construction. This log-book is to the car what the Service Record is to the soldier, and the driver is held rigidly responsible that it is not lost and that it is kept clean and all data entered up to date.

The driver's further responsibility is the proper loading and lashing of his cargo. It is very important that his truck is not overloaded and that his cargo is so placed that he will get traction, which in certain kinds of weather should be over the rear wheels, and he should watch that loading and unloading carefully. He does not do it himself, but he is charged with the responsibility that it is put on properly and that he gets a full load. Every vehicle in France must carry a full load every time it turns a wheel. We must insist on full loads as far as possible, due to the scarcity of equipment.

The company mechanic is also responsible for the tool equipment on the light repair truck which is part of the company equipment. He signs for these tools from the Company Commander; he signs for all spare parts and motor supplies issued to the company, and he issues all these things out to the assistant mechanics or drivers on memorandum receipts so that he has his records clear and in order at all times; and as I said before, the company mechanic is charged with the responsibility of keeping up this unit equipment list of the repair truck and the cargo trucks; this is done by requisition on the Service Park for tools that have been broken or worn out and for supplies that have been issued from the light repair truck. There is a unit equipment list for every type of vehicle that is operated in France. This unit equipment list includes all the necessary tools and a few small parts and supplies which should be carried with the vehicle at all times. Whenever tools are lost, broken or worn out the driver must immediately notify his Commanding Officer and arrange for the replacement of these articles without delay. As far as possible, such articles are replaced from the stock kept in the light repair truck. Everything about the truck that can be taken off or removed in any way is entered on this unit equipment list. The drivers are particularly responsible for everything appearing on the list.

The proper handling of a vehicle on the road will save a large amount of repair work in the company and will save spare parts, the value of which cannot be estimated in France. I want everyone of you to consider this fact when driving. Conserve your brake lining by intelligent use of the brakes. If you have a long hill to go down, throw your car into first or second gear, and only use your brake to bring the car to a dead stop on the hill. When it is necessary to make an emergency stop with the brakes, do not hold the brake on until it gets heated up and burns out the lining. When you get into a hole or a bad place and are stuck, be careful not to rip the facing off your clutch or strip your rear axle pinion. Never allow your truck to be over-loaded. If approaching a bump or hill in the road, slow down in order not to run the risk

of breaking a spring. Never attempt to back your truck unless you have some one walking back of it or standing in front of the truck to show you which way to go and how to avoid smash ups and accidents.

These are only a few things that you should watch and before you have finished your course we will attempt to warn you of as many other things as time will permit. Whenever your truck is standing idle on the road for loading or unloading, get out your oil can and monkey wrench and go over your truck carefully. If you do this you will catch troubles before they become serious and you will have to spend less time on your truck in the park and consequently have more time off to take care of your personal needs and for pleasure.

Conservation of everything shipped overseas for our troops is our watchword in France, and I want you to get into the spirit of conservation before going over so that it will become natural to you when you arrive.

One very important factor which will contribute enormously to the success of your organization is *team work.* I mean by team work, hearty co-operation between every member of the organization—a spirit of wanting to help each other, a spirit of pride in your organization, a serious viewpoint on the important work that you are doing. Be very jealous of the reputation of your company. Uphold its honor, protect its good name and at all times reflect credit upon it whether in camp or on the road or on leave. We call this *team work "Esprit de Corps"* in France, and you will hear a lot about it when you get "Over There." In order to make *Esprit de Corps* worth while to you, if such a thing be necessary, a system of rewards for efficiency and good service has been worked out whereby a driver who always has his vehicle ready to roll, who never has any criticism of the operation of his vehicle or of his personal appearance and conduct, receives time off, in addition to the regular company liberty, on certain stated days of the week. If his record is clean for a period of four weeks, a white star about 3 inches in diameter is stensilled on the side of his car underneath the driver's seat. This white star means that the driver has a record of excellence for a period of at least 4 weeks, and it is known throughout the A. E. F. to have that meaning. You cannot earn that white star nor have the time off, which I have mentioned before, if you are ignorant of what is expected of you and do not know how to keep your truck up, how to keep it clean and properly lubricated, etc. Therefore, it is up to you to learn these things so thoroughly that within the first two months after arrival in France you will have a white star on the side of your car.

We will now cover the responsibilities of a driver: first, to himself; second, to his Company Commander; third, to his truck, fourth, to the Service as a whole. All the points that I will cover will be the result of practical experience in service in France and for your own good and well worth remembering.

First of all, the driver's responsibility to himself. In France you are subjected to a great many temptations and you owe it to yourself and to the Service and to your family to keep your physical being clean at all times. General Orders will be read to you when you arrive in France covering this point, and you will be carefully instructed along the lines of personal appearance, which from my own observation know it deserves. You owe it to yourself to have your personal appearance, your clothes and your shoes always above reproach. There is nothing that reflects more credit on the A. E. F. than the personal appearance of its soldiers. England and France have devoted a great deal of attention to that point and America not enough. The result is that I have been heartily ashamed oftentimes when American drivers and either French or British have come together. The comparison was anything but flattering to the Americans.

Another point of responsibility to yourself is the spirit with which you enter into your work, the pride you have in your organization, and the personal pride as regards your own discipline in the camp or on the road or on leave. Do not take the matter of saluting and of respect for superior authority as an odious job which must be gone through with in order to avoid punishment. When you salute an officer you salute the insignia which he carries on his collar and his shoulders. That insignia means the Flag. It means the President of the United States. Its real meaning, if spoken by word of mouth would be: "I respect the responsibilities which the President has delegated to you. I honor my Flag and my Country and I am ready to carry out your commands." When the officer returns the salute its meaning is: "I know your loyalty and I shall try to lead you to the best of my ability." Never allow yourself to be lax in the matter of saluting. In fact, in France this matter of saluting is of paramount importance. The closer you get to the line or to the Front, the more rigidly this regulation is enforced.

Your responsibilities to your Company Commander are as follows: You must be absolutely obedient to his orders. Accept them without question or delay. Your Company Commander has additional information about certain movements of troops, certain contemplated changes of location of batteries, the condition of roads, and other things which are unnecessary to advise you of and which for military reasons cannot be published. For this reason when given an order to arrive at a certain point at a definite time, let nothing under heaven interfere with your being there. A tremendous lot may depend on your truck being on time and being at a certain point without any question of doubt or peradventure. When given an order to go to a certain dump, to transport certain definite quantities of supplies, never leave that dump without the required number of fuses, shells, etc., that are noted on the order. Shells are no good without fuses, and fuses are no good without shells. The same applies to subsistence stores which are hauled from Quartermaster dumps. You do not want the boys in the line who are doing the fighting and risking their lives every second of the day and night, to be short anything of any nature that will help them to win out. I want you to feel that responsibility. Your Commanding Officer will be very severely criticized in case you do not carry out his instructions to the last detail and you do not want your C. O. and your entire organization to suffer because of your laziness or carelessness.

Another responsibility to your Company Commender is absolute loyalty. Even if your C. O. is not all that you would wish him to be, be loyal and uphold his reputation to the best of your ability. He represents your company and unless his record is clean in the eyes of other organizations and other people, your company record will suffer accordingly. Whenever your C. O. passes or enters the room where you are resting never fail to salute. Respect his authority, respect his responsibility, and be always on guard to protect his and your company's reputation.

The driver's responsibilities to his truck and equipment are numerous. You are entrusted with a good many thousands of dollars worth of Government property. This equipment at times has a value which cannot be estimated for several reasons. First of all, due to the lack of ships' tonnage and the activities of the submarine, it is extremely difficult, and up to the present time impossible, to get enough equipment to France to move the freight. Every vehicle must do the maximum amount of work of which it is capable in order to render the service with which the M. T. S. is charged. At times, for strategical and tactical reasons, your truck may be the means of turning the tide in favor of our boys in the lines and at those times your truck off by itself or in company with a few others, is beyond estimation of value. One truck drvier at Chateau

Thierry practically saved the day for our Marines by bringing up machine gun ammunition at the psychological moment under terrible fire, and delivering it in full sight of the Germans and in the face of their fire.

Whenever you take over a truck in France you sign for the truck and its equipment. By this equipment I mean the tools, the small parts and supplies. The tarpaulin and bows, the lamps, fire extinguishers, towline, pick and shovel, and all the other equipment which you will find on the unit equipment list for a truck. This unit equipment list is standard and is made out in duplicate at the time the truck is put into service. The original is printed on cardboard and is to be kept in the truck at all times. You are responsible for the items checked or marked on this cardboard and if, when your turn the truck over to another driver, anything is lost or stolen, you must pay for it. No excuses are accepted and none should be given. This is made necessary for several reasons, but the main reason is that equipment is too scarce and too valuable and too difficult to replace in France. When you use an extra spark plug from your tool kit, go immediately to the company mechanic and requisition for a new one. When you use cotter pins, nuts and bolts, or the valve spring or valve from your truck equipment, immediately get the same supplies from the company mechanic to replace them. Never allow your equipment to get down under any circumstances. These supplies and these tools that appear on the list are the minimum amounts which are necessary to keep your truck in service. Therefore, you do not want to be caught short of any of these things when emergencies arise on the road away from your company park or a repair park.

For the same reason that you must keep your personal appearance what it should be, and for other reasons which I will enumerate to you, you must always have your truck or car or motorcycle spotless and in adjustment. When I say spotless I mean just what the word implies. You will see British and French equipment when you arrive in France, and that sight will be an incentive for you to keep your vehicle clean at all times. When a vehicle is properly cleaned and lubricated there will be a minimum demand for spare parts and supplies. These supplies are very difficult to get in France and we will never have as many as we need. The proper way to clean your truck will be shown to you during this course. You will be shown show to clean your engine, what parts, such as spark plugs, porcelains, wire terminals, etc., should be guarded against breakage. You will be shown what parts should be cleaned with a brush and what with a cloth or with waste. The same applies to other parts of your vehicle throughout the chassis. You will not have gasoline or kerosene to get this grease and dirt off quickly, but you will be provided with a solution of sal soda and water which will cut the grease and do just as good a job as kerosene or gasoline which are such valuable supplies to us. When you have your engine thoroughly cleaned, including the pan underneath, start in on your transmission case, the short shaft between the transmission and the clutch, and the pan and the frame around these assemblies, then go to the rear axle. Clean the housing, the brake mechanism, the propeller shaft and universals, the torque rods and connections, the brake equalizer and connections, and do not shirk a single thing. Then wash the body and chassis of your truck thoroughly. When the entire vehicle has been cleaned, go over it carefully with an oil can and lubricate all the connections not supplied with grease cups, turn all grease cups down one turn, and if there is any question of whether the grease is getting to the bearings when the cup is turned, turn the cup down as far as it will go, and if necessary, fill it up again and turn it down a second time until the grease actually shows up around the joints or bearing. Make sure that the part is being lubricated. More parts and supplies are

needed for motor vehicles because of lack of lubrication than for any other cause. Test the oil in your crank case, in your transmission, in your differential. See that you always have the proper grade and kind of oil for the assemblies. Take off your wheels periodically, at least once a week, and see that the bearings are properly lubricated and adjusted. Outside of driving, your main duties while in camp or during delays on the road at loading and unloading points are to clean and lubricate your vehicle. This is one of the most important points that I can touch on during this course, and I want you to give it the attention which I know it deserves and which will be required of you in service in France.

In the matter of adjustment which you will be called upon to make and which is another responsibility which you have to your truck, a definite list of these which will be taught the drivers will be furnished to your instructors. There has been not a little discussion in the United States as to the amount of actual mechanical work which a driver will be called upon to do, or rather that which a driver should know and be instructed in at M. T. C. Schools. You will be thrown on your own resources very often where it will be necessary to make minor adjustments to your fan belt, your carburetor, your electric system, your clutch, your wheels, steering gear and your engine. Ordinarily, in your company park you are charged with reporting parts that are out of adjustment or broken or in need of repair to the company mechanic. He either directs you to make the adjustment, at the same time instructing you how to do it, or he details one of the assistant mechanics to do it for you. All repairs and adjustments in park and on the road are absolutely under the direction and supervision of the company mechanic. If he is not present on the road when you are traveling alone or in a small convoy, you must make emergency repairs and adjustments. Therefore, get all you can from the lectures and practical work during the course, as to the construction of your vehicle and the adjustment of its different parts. Most important of all is the tightening of loose connections, nuts and bolts before they cause further serious trouble. You must always be on the watch for such trouble. Learn to use your monkey wrench or spanner or screw driver, but there is a lot to be learned on that point. For instance, if a monkey wrench is not tightened up, when you attempt to turn a nut the wrench will slip and probably skin your knuckles, but worst of all, will so mutilate the nut that no kind of a wrench will tighten it. Always have your wrench adjusted properly and do not attempt to pull the nut so tight you will strip the threads or break off the bolt. This is very easily done unless you are careful. If you have not the proper size open end wrench with which to do the work, take a larger spanner than the one required, insert a washer or a piece of steel between the nut and the jaw of the wrench, and you have a tool that will do the job. These are only two instances to show you that there is such a thing as intelligent use of tools, and you will be called upon often times, due to shortage in your equipment, to be resourceful in the use of what you have. At least once a day in the park go over every nut and bolt and connection on your truck to see that everything is in shape. Have a rag or a piece of waste under your seat with which you can wipe off the engine and chassis and body. If you do this you will catch troubles that might develop in the next mile that you travel, and in addition you will have less work to do when you get back to the park. Should the truck be put out of commission through your fault, you are tying up equipment which, as I told you before, is invaluable. Of course, if your truck is struck by shell fire or is called into the Service Park for periodical overhaul, that is not your fault. Those are the only two times, however, when it can be out of service without reflecting discredit on you.

There are all sorts of punishments possible and every one is used for men who do not keep up their equipment and who are lax about their discipline and

personal appearance. Those punishments vary from K. P. work and extra duty to loss of pay and even general court-martial proceedings. As is only right, there are, on the contrary, rewards for those who behave themselves and are careful of the equipment entrusted to them. One system of rewards has been worked out and is in operation in France and consists of extra time off outside of the routine company liberty, and in promotion to higher grades. I will tell you of this plan of rewards in my next lecture.

The driver's responsibility to the Service as a whole is very great and far reaching. In the present war, motor transport occupies a very prominent place. The German Army, due to the lack of gasoline and rubber for tires, and due to the fact that it has been educated to the use of railroads and horse-drawn vehicles transports nearly all of its supplies by light narrow-gauge railroad, right up to the line. It uses a minimum amount of motor transport. On the other hand, all of the Allied Armies, and particularly the French and American Armies, rely almost entirely on motor transportation. Supplies are brought up to what is called the rail-head from the supply depots far in the rear. The rail-head is usually 8 to 15 miles from the front line, by motor transport. From distributing point to the regimental kitchens, supplies are carried by animal drawn transport. It very open happens, though, that trucks must deliver supplies direct to the regimental dumps which are immediately back of the line and farther forward than the distributing point. That important gap which is filled by motor transport from the rail-head to the distributing point is the area in which you will operate in France. You can plainly see your great responsibility to the Service as a whole, which is to move the freight and deliver the supplies, often times under shell fire, over roads that are crowded with guns, troops, vehicles of all description, in sunshine and rain, and night and day, to the boys in line. The better service you render to the Army and to your Country, just that much quicker will we be back in our homes away from all this ghastly business, and the quicker you will bring about a successful issue for your own and the Allied Armies. You must have unlimited pride in the fact that you are an American soldier. Your personal appearance and deportment, if correct, will prove the greatest advertising factor which this country could put out to the Allied Armies. This is a mighty serious business that we are engaged in and only when you are on leave can you sit down and think of lighter things, but even then you must carefully protect the good name of the United States and the Flag.

We will now speak first of the class of repairs and adjustments that you as a driver must be conversant with, and secondly the details of your responsibility and accountability for equipment placed in your charge.

There are three things about a motor car or a motor vehicle which require constant looking after in France. They are all of equal importance and it is hard to say that one should have more emphasis than the other. You should know how to drain your carburetor and clean out the dirt which is sure to collect. Gasoline as it arrives in France is of very poor quality. It contains impurities such as water and allow both the pipe and the carburetor to drain. Water also accumulates in the bottom of the tank. However, by allowing the gasoline to run out of the feed pipe, when disconnected at the carburetor, into a pail or can, both the tank and the pipe will be pretty thoroughly cleaned out. This work must be done with great care in order not to lose any of the gasoline during the operation. By careful handling the gasoline can be poured back into the tank leaving the water in your can. There is usually a strainer in the feed pipe and this should be kept clean at all times.

You should know the adjustment of your carburetor. When you are in the park or on the road with your company the adjustment of the carburetor will always be made by the company mechanic or his assistants. It might happen, however, that you are on the road alone without the mechanics and emergency adjustments will be found necessary. You must be able to distinguish between a surge in the motor caused by improper adjustment of the carburetor and a surge in the motor caused by one or more of the cylinders not firing. You must know that when a popping noise is in your carburetor you have either got water or dirt under the needle valve or too thin a mixture. The first thing to do would be to drain the bottom of the carburetor and the feed pipe to see if water or dirt has gotten in there. If that does not correct the trouble you should know how to adjust your needle valve to get a richer mixture. It is impossible to show you or to tell you so that you would understand without models to demonstrate this with. This adjustment and those which I will call your attention to later will be given to you in your laboratory and practical work. Pay particular attention to the points which I will bring out in this lecture, for they are points which we have learned are important in France after one year's experience.

The next point is the adjustment and equalization of your brakes. The country over which you will be operating near the front line is very hilly and there are constant demands on the brakes. The result is that they require almost daily attention. Before attempting to go down a steep or a long hill, slow down and shift to first or second speed before getting over the crest of the hill. Your engine then acts as a brake and, except in cases where it is necessary to make an emergency stop, your foot and emergency brakes will have to be used but little. If, for any reason, you do not have time to change gears before starting down a hill, use your foot brake for a few seconds and then shift over and use the hand brake. Alternate in this way all the way down the hill. Never use one brake continually for any length of time as it not only wears it out quickly but it is almost sure to get hot and bind. The result is that your truck comes to a dead stop and ties up all of the trucks back of you. This is a point you must remember. "Above all things keep your truck in motion when operating in a convoy." If it is impossible to keep it running, pull your truck as far as possible to the right hand side of the road, even into the ditch if necessary, so that other vehicles can pass you. However, if the brakes are carelessly used and seize, you will find it impossible to run your car or even to push it out of the way until the brake drums and the lining have cooled off. For that reason you must be doubly careful not to have this occur. It is not your own truck alone that you are putting out of service temporarily, but you are tying up perhaps five miles of trucks back of you. Test your brakes two or three times a week at least to see that they are equalized. This is done by jacking up both rear wheels, setting your hand brake so that it is just possible to turn the rear wheels by hand, then see that the brakes take hold approximately in the same way on both. Then have some one sit in the driver's seat and hold the foot brake down part way and test both rear wheels to see if the foot brake is equalized. If you are not careful about this point your troubles with skidding will greatly increase and you will lose a great deal of the efficiency of your brakes. Watch your brake lining carefully and anticipate the necessity for renewal of this lining before it actually wears out. Due to the almost constant operation in convoy it is absolutely essential that your brakes be in excellent shape. Any accident which you may have in operating your vehicle in France is investigated very thoroughly by a commissioned officer. You as a driver must not only prove that the accident was not your fault but you must also prove that it was a

physical impossibility on your part to avoid it. So you see the importance of having your brakes well adjusted and being able to control your car at all times so that you will not smash your radiator or have the rear end of your truck knocked out.

The next is the cleaning of spark plugs and adjustment of points and the tracing of ignition troubles. Your spark plugs should be cleaned very often, at least twice or three times a week. Be very careful in taking them out of the ports that you do not break the porcelains. If you are careless in the use of your monkey wrench or spanner or if you drop the spark plug after you have taken it out, you are liable to break this porcelain and you will have to have a new plug before you can operate. If you do break a porcelain it is up to you to explain exactly how it happened and prove that it was not due to carelessness on your part. The actual cleaning of a spark plug and the adjustment of the points will be shown to you during your course. I will only dwell on the importance of keeping them clean and the importance of your knowing how this is done. You will also be shown during this course how to trace ignition troubles. Ignition troubles should always be turned over by you to the company mechanic, with the exception of the cleaning of spark plugs. The adjusting of the points must be done by the company mechanic unless he is not around and it is impossible to arrange for him to do it.

I have prepared a list showing the adjustments and repairs with which you as drivers should be acquainted, and which you should study during your course. A copy of this is attached to this lecture and copies will be distributed to you for your guidance. The more you know about your vehicle and the better you know the adjustments and repairs which must be done on it, the quicker you will get promotion and reward, and the more service you will render to your company and to the Service as a whole. You may think you know all about it but I can truthfully state that no one ever knew all there was to know about a truck or automobile. Men have made a life study of it and are still learning every day. Whenever I hear a driver brag about what he knows and saying that there is not a thing about his truck that he does not understand and that there are no repairs which he cannot make, I immediately put him down as the least efficient of the outfit. Do not brag about your knowledge, but dig in and learn it and show it in the operation of your vehicle and in the way you keep it up. If you master the three adjustments mentioned above, you will have a minimum of difficulty in keeping your truck in service at all times.

I will outline to you the extent of your responsibility for the motor equipment placed in your charge. Whenever you are assigned to a truck, a memorandum receipt is made out by your Commanding Officer giving the make and type of truck, serial number, motor number and list of all the equipment on the truck at the time of transfer. This memorandum receipt is known as M. T. S. Form 101. All assignments and all transfers are recorded on this form in France. The Unit Truck Equipment is shown on page ninety-two of the Manual and you should be sure that every article called for is actually received before you sign the memorandum receipt. This form is in quadruplicate and is made out by the person transferring the equipment and is signed by the person receiving the equipment. This remains a permanent record in the office and is used in checking up periodically for shortages, breakages and loss on your truck. Any shortages will be taken out of your pay roll at the end of the month. No excuses are accepted and none should be necessary. You are responsible for a good many thousands of dollars worth of Government property. As I have told you many times before, the truck and its equipment are almost impossible to replace in France. That is

why you will be held pecuniarily responsible for it. Whenever you are relieved from your truck and another driver takes charge of it, you must make sure that he signs for this equipment and that everything is checked off against the original list. If this is not done you may find a few days or weeks later that you will be charged up with certain tools and supplies and made to pay for same, whereas their loss occurred after you had been relieved from your truck. As you are aware, the Army need not consult you about taking money out of your pay for loss or damage to Government property. This is something that is beyond your control. When you take over a new truck that has been in use by some other driver, use all care to see that he does not "Put anything over on you," as we express it. If he is short of equipment he will try very hard to get you to sign for things that actually do not exist. You have got to have your eyes wide open and not take his word for anything.

At all formal inspections your equipment is checked over against the list as it appears on M. T. S. Form 101, Memorandum Receipt. These inspections are held about once every month and perhaps oftener. You will find it much easier and better all around to report loss or damage to equipment *immediately* after it occurs rather than let it slide until an inspection takes place. I know this from my own experience. Losses are bound to occur even though you use the greatest diligence and care. It is much better, therefore, to report such things to the Sergeant Mechanic or Commanding Officer and get it over with at the time that it happens rather than take a chance at getting by with it a week later when a formal inspection is held.

When you take your truck to a Service Park for repairs, all of your equipment is taken off and checked against your copy of M. T. S. Form 101, which is carried with you at all times. This equipment is done in a bundle and placed in the stock room for safe keeping. When you return a day or two later to take your truck away the bundle of equipment is taken out of the stock room and spread out on the ground and rechecked according to your list. Any shortages appearing in the equipment when you report to the Park with your truck are noted, and when you leave the Park with your repaired truck make sure that you get everything you are entitled to according to your list. If tools or supplies have been stolen while your truck was in the Park, report same at once to the Commanding Officer of the Park and insist that the stolen parts be replaced before you leave to return to your organization. These things that I am telling you are for your own good and most of them are things I have learned by hard experience.

Never allow any other man to drive your truck except the assistant driver who is assigned to you. You must make this a hard and fast rule, for if you do not, and you allow another man to operate your vehicle and he suffers an accident or steals any part of your equipment, you are the one that is held responsible for it.

MOTOR TRANSPORT CORPS

EXECUTIVE DIVISION—TRAINING BRANCH

Motor Truck Company Drivers' Course

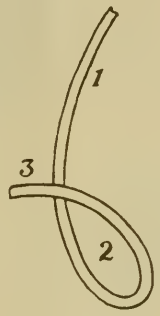
KNOTTING AND SPLICING

LECTURE I

SIMPLE KNOTS AND SPLICINGS

The art of working in rope cannot be learned from a book, but the illustrations which follow are used to give an idea of the most common knots and splices of value to truck operators and should be studied and mastered.

Fig. 1



There are three qualities to a good knot:

1. Rapidity with which it can be tied.
2. Its ability to hold fast when pulled tight.
3. The readiness with which it can be undone.

To understand clearly the explanations and descriptions of the various knots, one must have clearly in mind the three principal parts of a rope. (Fig. 1.)

Fig. 2

1. *The Standing Part.*—The long unused portion of the rope on which he works.

Fig. 3

2. *The Bight.*—The loop formed whenever the rope is turned back upon itself, and

3. *The End.*—The part used in leading. (Fig. 1.)

The following knots are most commonly in use by truck operators:

1. *Square Knot* (Fig. 2).—The commonest for tying two ropes together. Never slips or jams; easy to untie. (Fig. 2.)

2. *Slip or Running Knot* (Fig. 3).—A bight is first formed and an overhand knot made with the end around the standing part. (Fig. 3.)

Fig. 4

3. *The Bowline* (Fig. 4).—A noose that neither jams nor slips. Form a small loop on the standing part leaving the end long enough for the size of the noose required. Pass an end up through the bight, around the standing part and down through the bight again. To tighten, hold noose in position and pull standing part.

Fig. 5

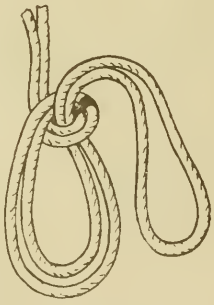
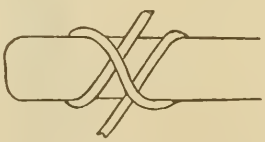


Fig. 6

4. *Bowline on a Bight* (Figs. 5-6).—Used in place of a single bowline where greater strength is needed. (Fig. 5.) (Fig. 6.)

Fig. 7



5. *Clove Hitch* (Fig. 7).—Used to fasten one pole to another; this knot holds snugly and is not liable to slip laterally. Hold the standing part in the left hand, cross the standing part, making a second turn around the pole, and pass the end under the last turn.

6. *Two Half Hitches* (Fig. 8.)—Useful because they are easily made and will not slip under any strain. Their formation is sufficiently indicated by the illustration. (Fig. 8.)

Fig. 8

Splicing is joining the ends of two ropes permanently or bending back the end of a rope upon itself to form a permanent eye.

The following are a few methods of splicing in use:

1. *Eye Splice* (3 stranded rope).—The rope is unlaid for perhaps a foot from the end, and the strands brought back upon the body of the rope at a point which will form an eye of the size that is desired. Beginning with any one strand, this is tucked from left to right through the strands of the rope, being passed over one and under the next. The other strands are similarly

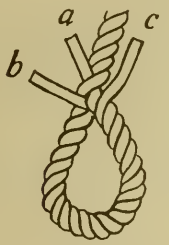


Fig. 9

Fig. 10

Fig. 11

Fig. 12

tucked always from right to left. All are then trimmed down to two-thirds their original size, tucked again, trimmed to one-third size and tucked a third and last time. (Figs. 9-10-11.)

Where the rope is four strands, the first strand is tucked under two but this is for the first tucking only. (Fig. 12.)

Fig. 13

Fig. 14

2. *Short Splice* (Figs. 13-14-15).—Two ropes are unlaid for a short distance and married together with strands interlacing. The strands are then tucked through the lay of the other rope exactly as has been described in the case of an eye splice. (Fig. 13.)

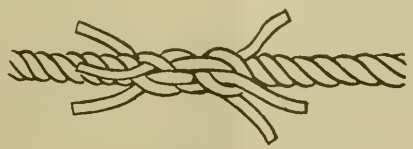


Fig. 15

3. *Long Splice.*—Here the ropes are unlaid for a greater distance than for a short splice and the ends brought together as before, with strands interlacing.

Instead now of tucking at once, we proceed as follows: (See illustrations.) Unlay *a*-1 one of the strands of A, for a considerable distance, and in place of it lay up *b*-1, the adjoining strand of B, thus working a strand of B into A for, say, a foot and a half or two feet. For convenience now twist up *a*-1 and *b*-1 together temporarily, as in Fig. 17. Turn the rope end for end, unlay *b*-2

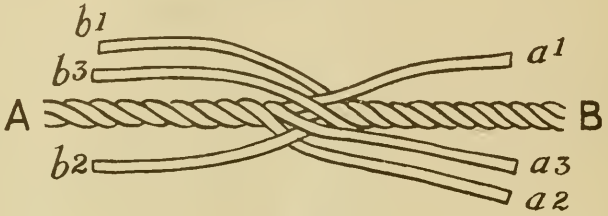


Fig. 16

one of the strands of B, and in place of it lay up *a*-2 the adjoining strand of A. *a*-3 and *b*-3 are left lying beside each other without being unlaid. We now have three pairs of strands at different points of the rope. Beginning with *a*-2 and *b*-2 (for example) separate each strand, overhand knot these together (Fig. 17) and tuck them as in short splice, over one of the full remaining strands of the rope. (Fig. 17.)

The other pairs of strands (*a*-1, *b*-1) (*a*-2, *b*-2) are similarly reduced knotted and tucked. The spare half of each strand is trimmed off smooth as are the ends of other halves after they have been tucked.

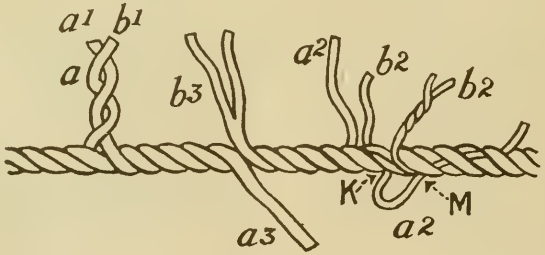


Fig. 17

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